US011912399B2

(12) **United States Patent**
Allen

(10) **Patent No.: US 11,912,399 B2**
(45) **Date of Patent: Feb. 27, 2024**

(54) **COMPACT AIRCRAFT ACTUATOR SYSTEM**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 126 days.

(21) Appl. No.: **17/675,789**

(22) Filed: **Feb. 18, 2022**

(65) **Prior Publication Data**

US 2023/0264808 A1 Aug. 24, 2023

(51) **Int. Cl.**
B64C 25/22 (2006.01)
F16H 19/00 (2006.01)

(52) **U.S. Cl.**
CPC ***B64C 25/22*** (2013.01); ***F16H 19/005*** (2013.01)

(58) **Field of Classification Search**
CPC B64C 25/22; B64C 25/50; F16H 19/005; B62D 5/10; B62D 5/12; B62D 5/20
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,856,138	A	10/1958	Hogan	
3,444,784	A *	5/1969	Wengerd	F15B 15/065 91/533
6,289,788	B1	9/2001	Holtom	
8,312,784	B2	11/2012	Bonny	
9,908,621	B2	3/2018	Didey	
10,940,942	B2	3/2021	Morris	
11,066,154	B2	7/2021	Morris	
2015/0000433	A1 *	1/2015	Farcy	F16J 1/16 74/30
2016/0272307	A1 *	9/2016	Perkins	B64C 25/10
2016/0318604	A1 *	11/2016	Guery	B64C 25/50

FOREIGN PATENT DOCUMENTS

EP	0741073	3/2002
FR	2558554	7/1985

OTHER PUBLICATIONS

European Patent Office, European Search Report dated Jul. 3, 2023 in Application No. 23156745.4.

* cited by examiner

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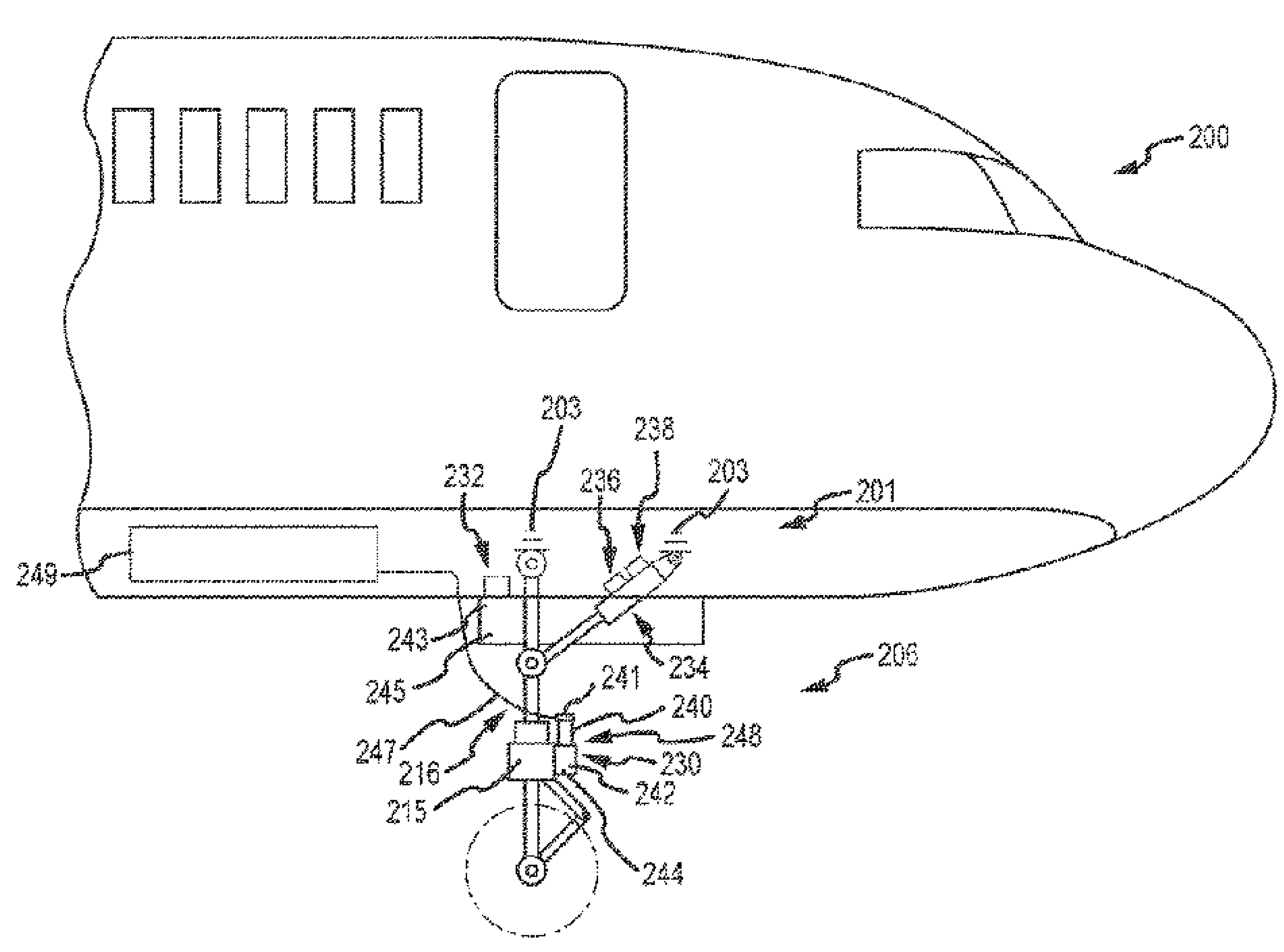
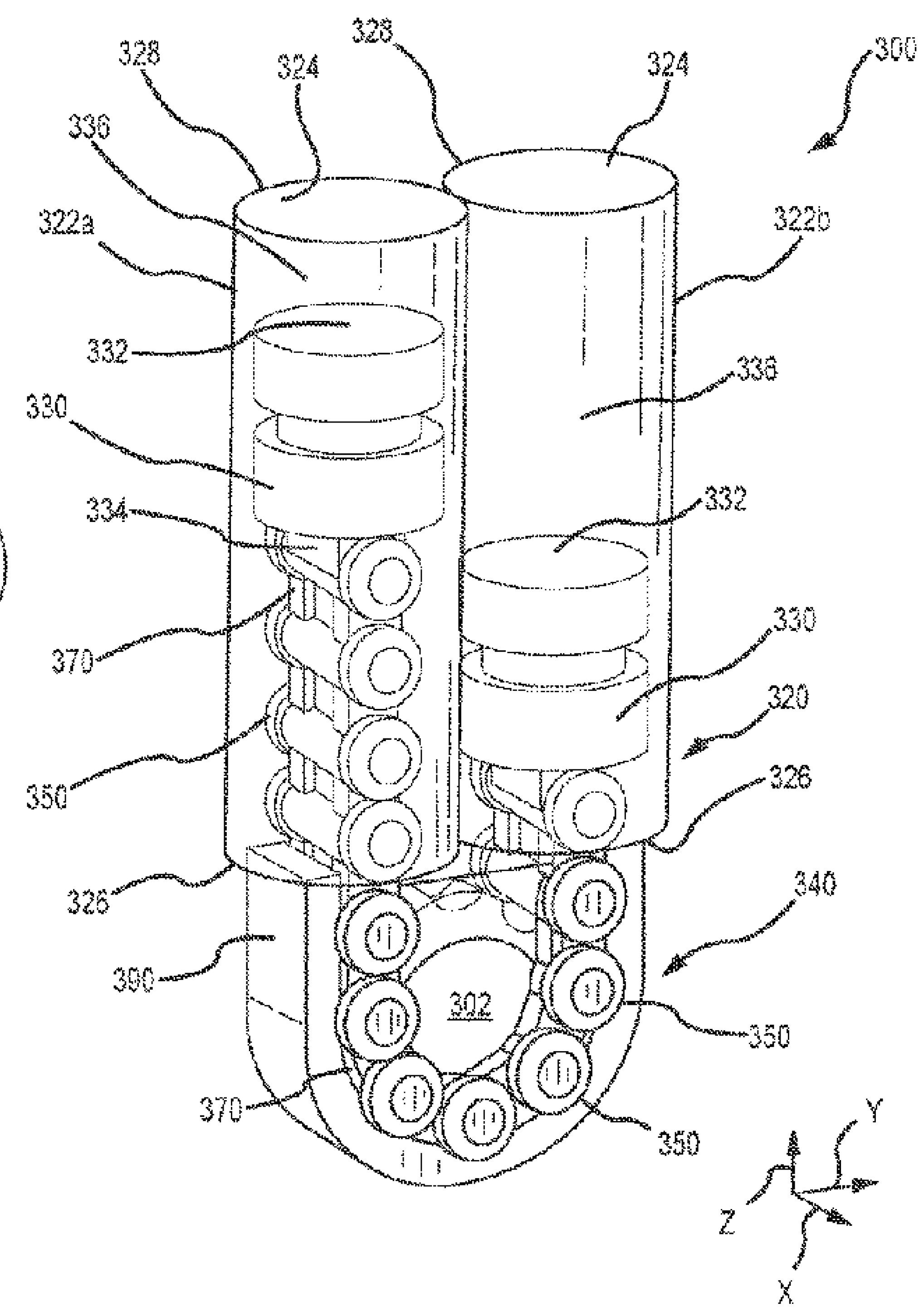
(57) **ABSTRACT**

An aircraft actuation system is disclosed that includes a pair of cylinders, a piston movably disposed in each cylinder, and a roller train that extends between the pistons in the two cylinders. A portion of the roller train is disposed beyond the cylinders to engage a pinion. Movement of the pistons in the two cylinders in opposite directions produces a corresponding movement of the roller train to in turn rotate the pinion. The roller train may be maintained in compression between its two ends by fluid pressure exerted on a common face of each of the pistons in the two cylinders. The cylinders may be disposed in non-colinear relation, including in parallel relation to one another. A guide may be used to maintain rollers of the roller train in a proper orientation for entry into a space between an outer race and the pinion.

19 Claims, 12 Drawing Sheets





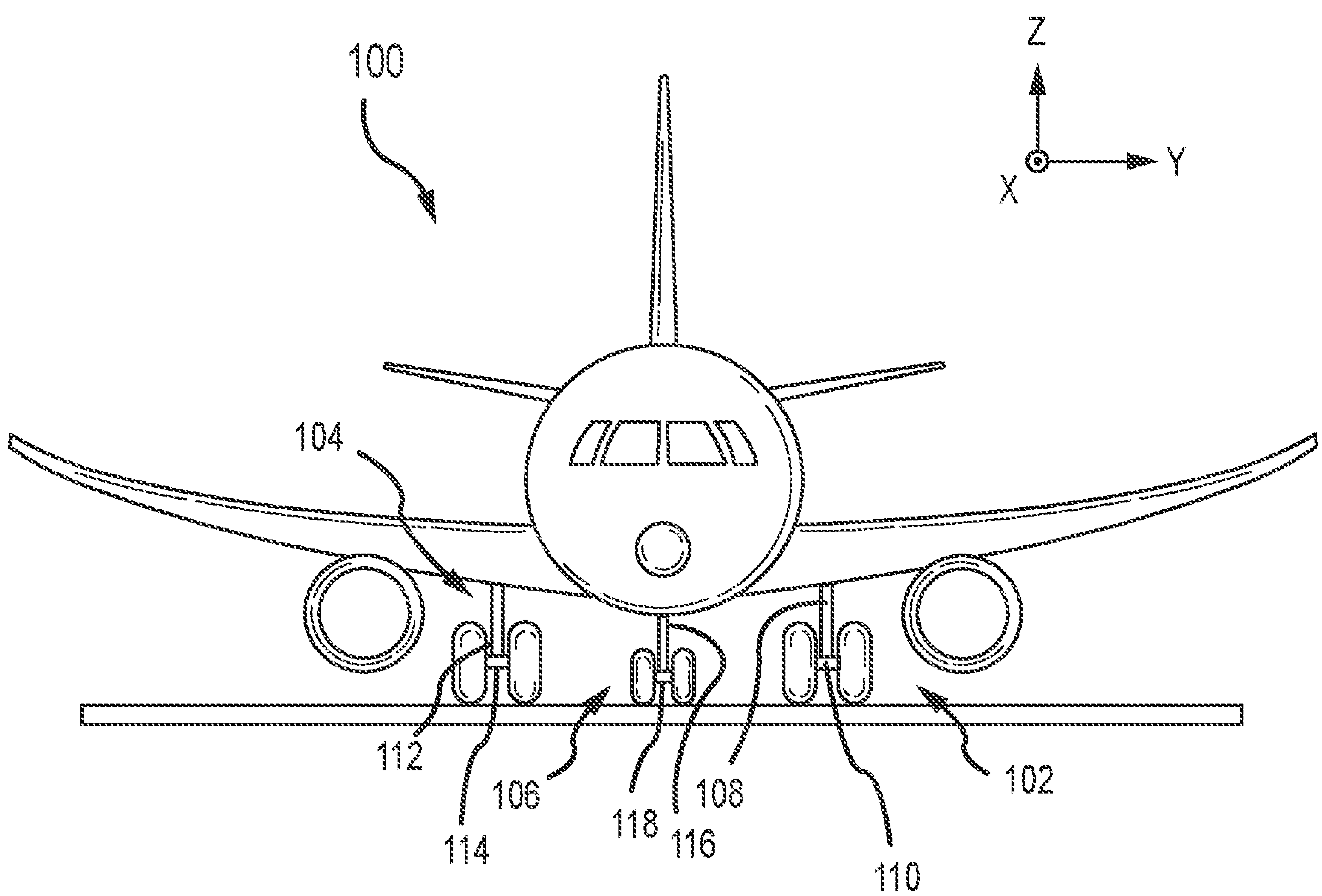
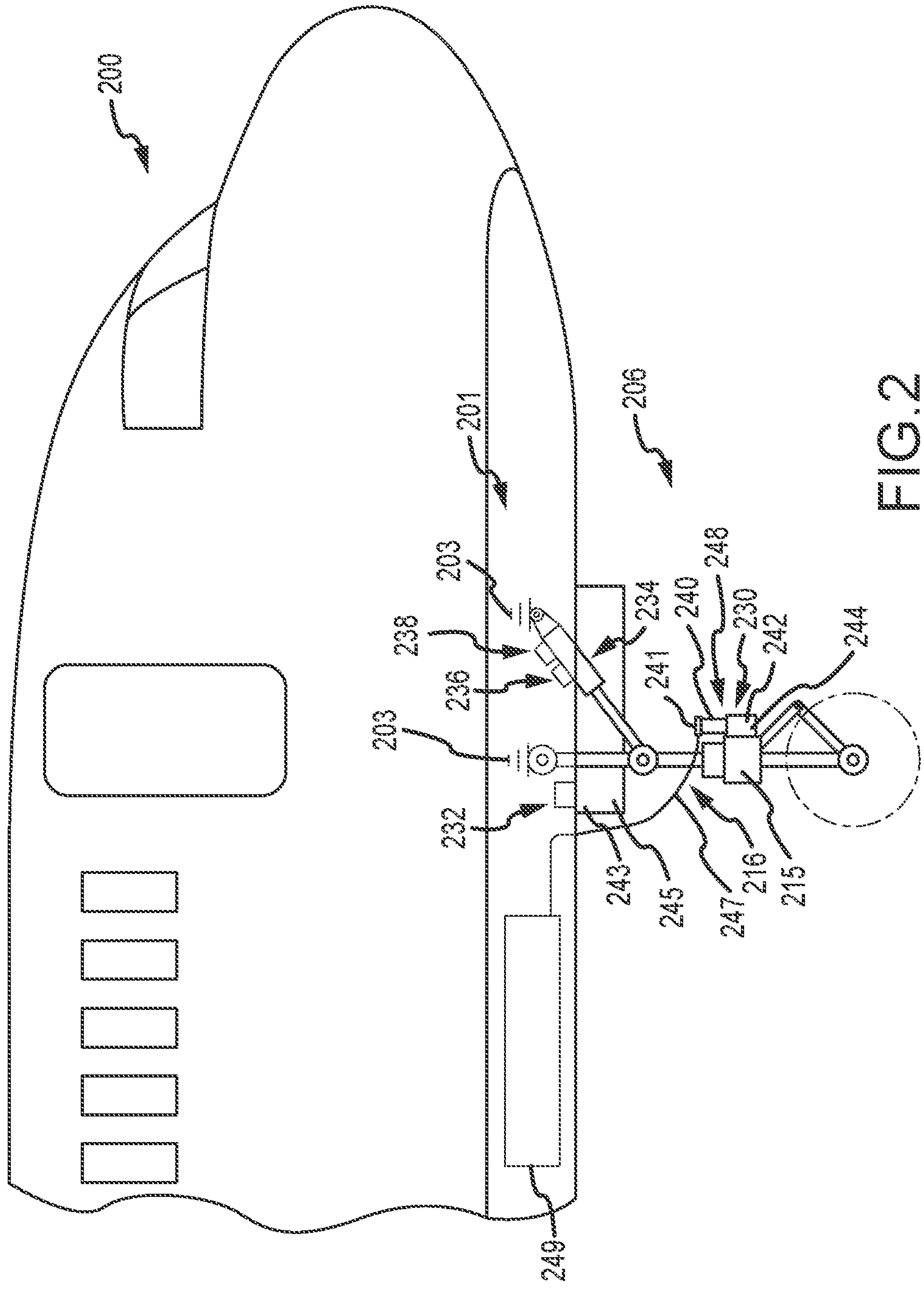


FIG.1


200
201
206
203
238
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216
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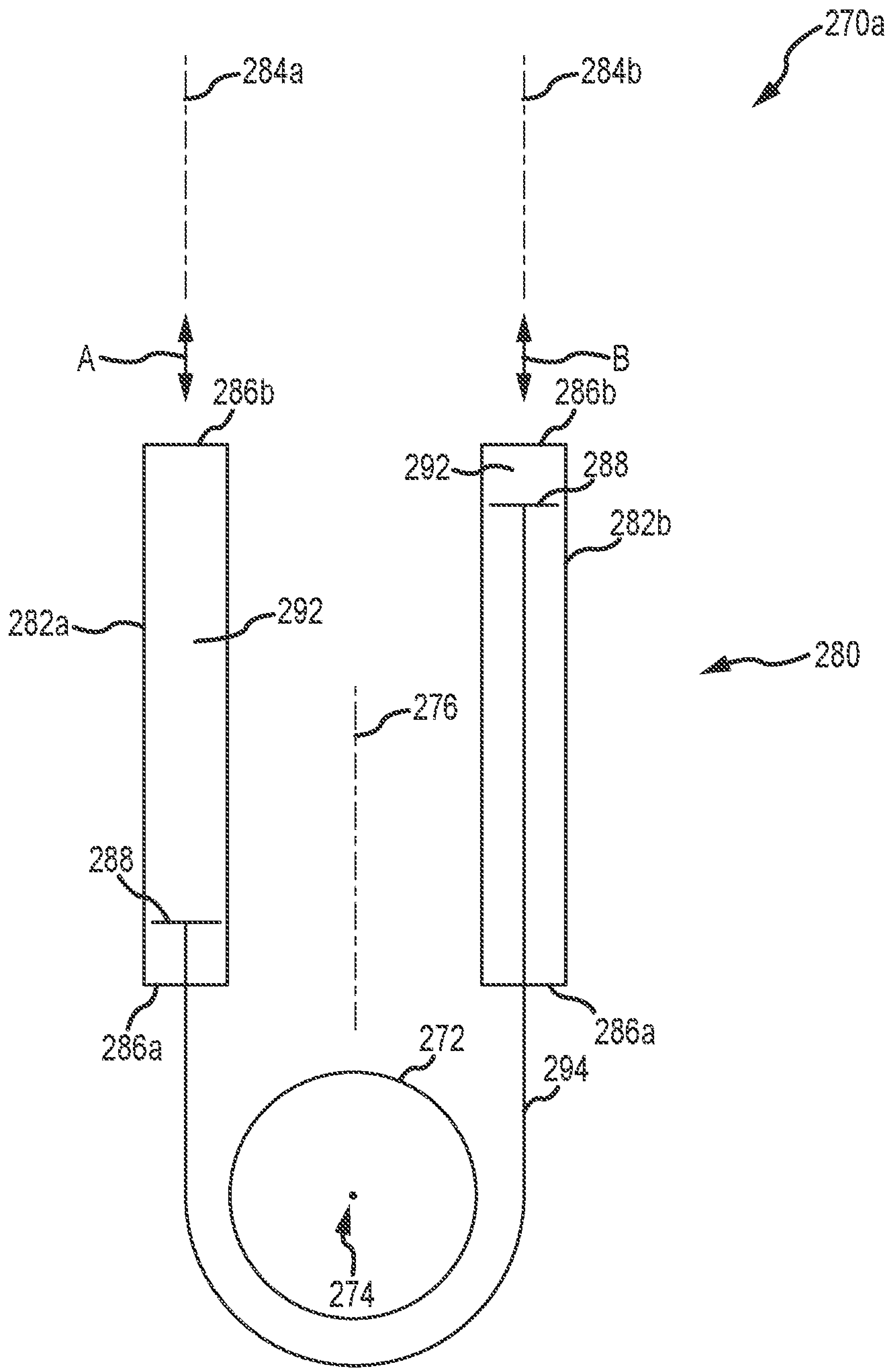
249

FIG. 2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284a
284b
A
B
286b
286b
292
288
282b
282a
292
280
276
288
286a
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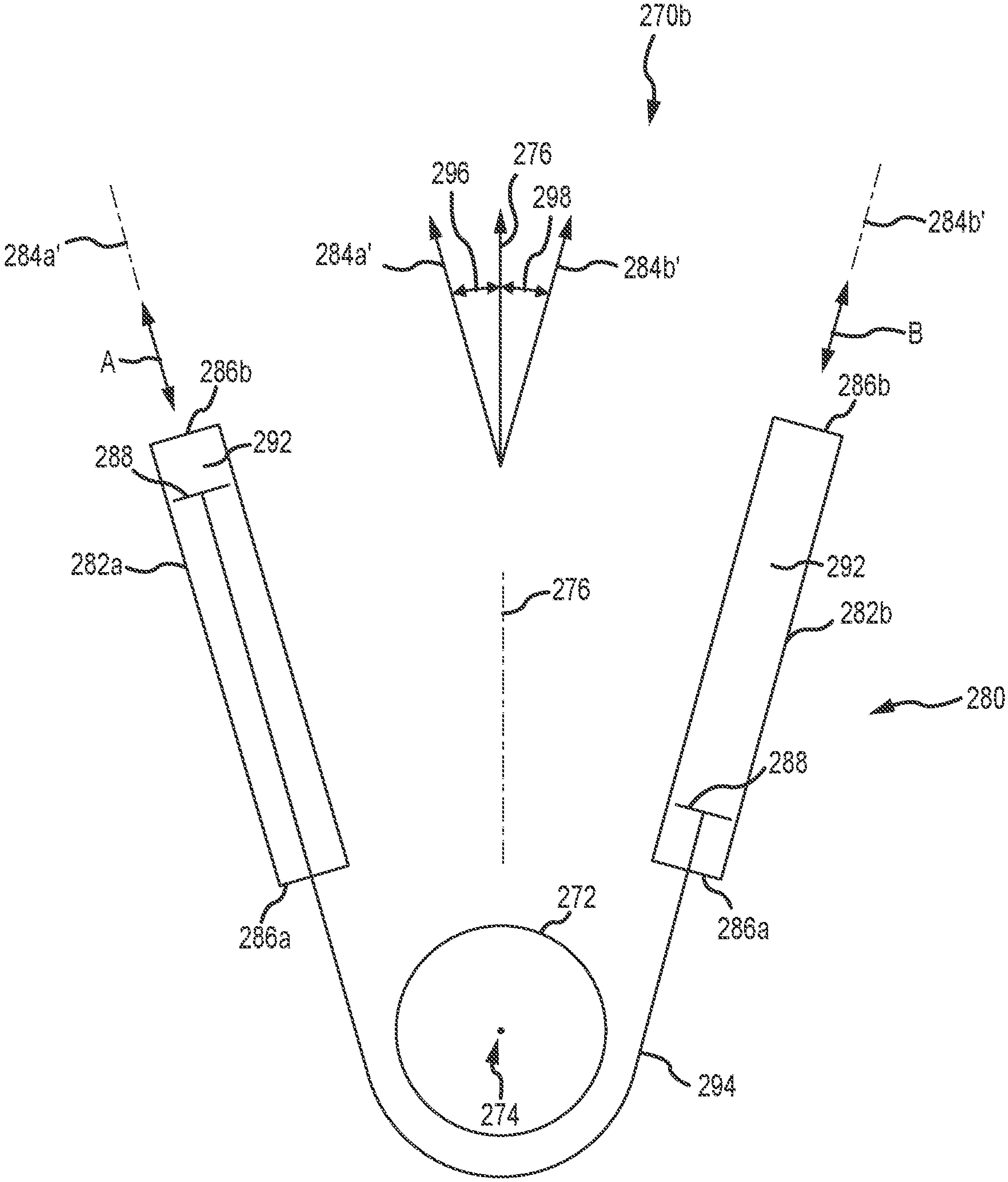
272
294
274

FIG.3A


270b
276
296
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284a'
284a'
284b'
284b'
A
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272
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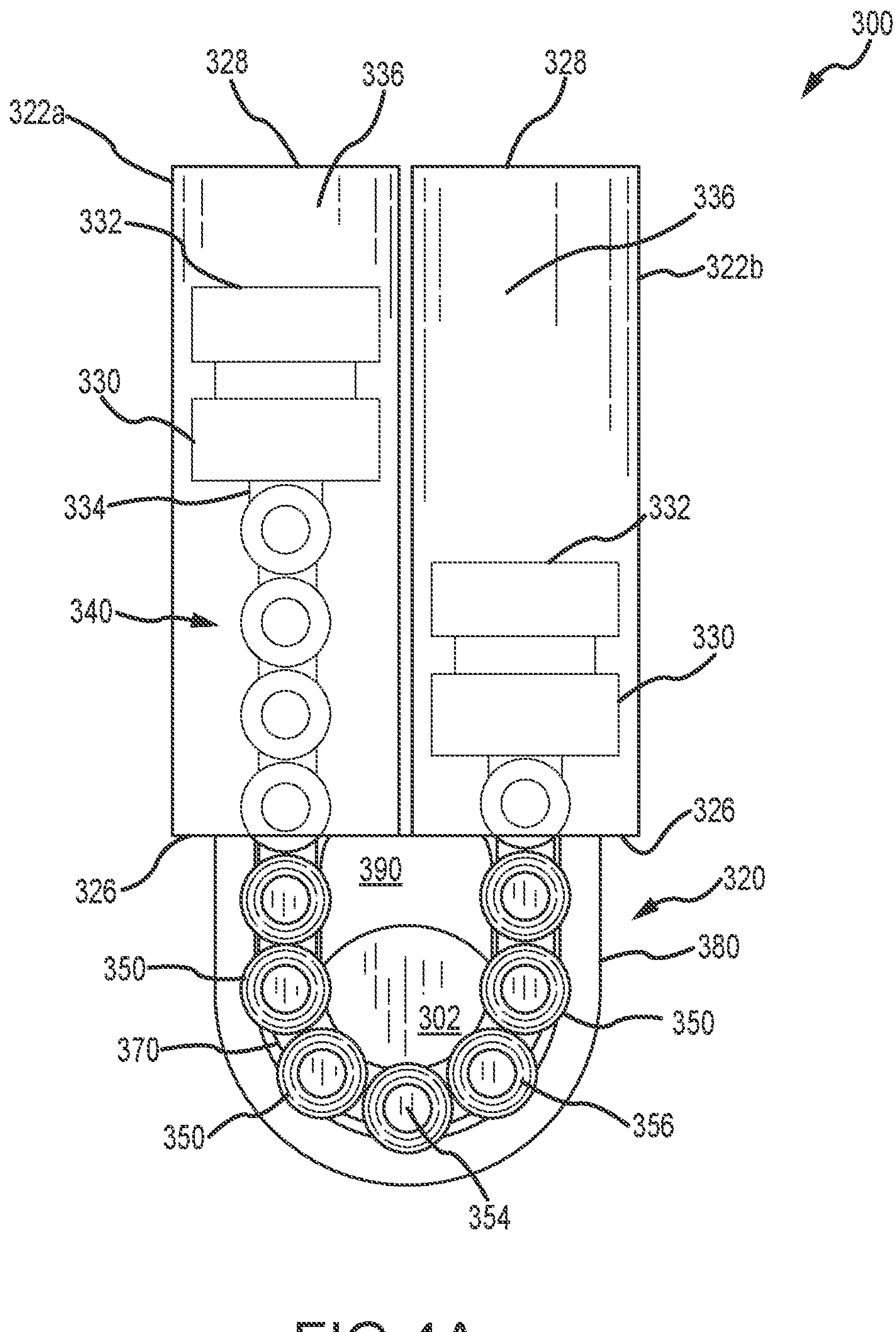
274

FIG.3B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322a
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322b
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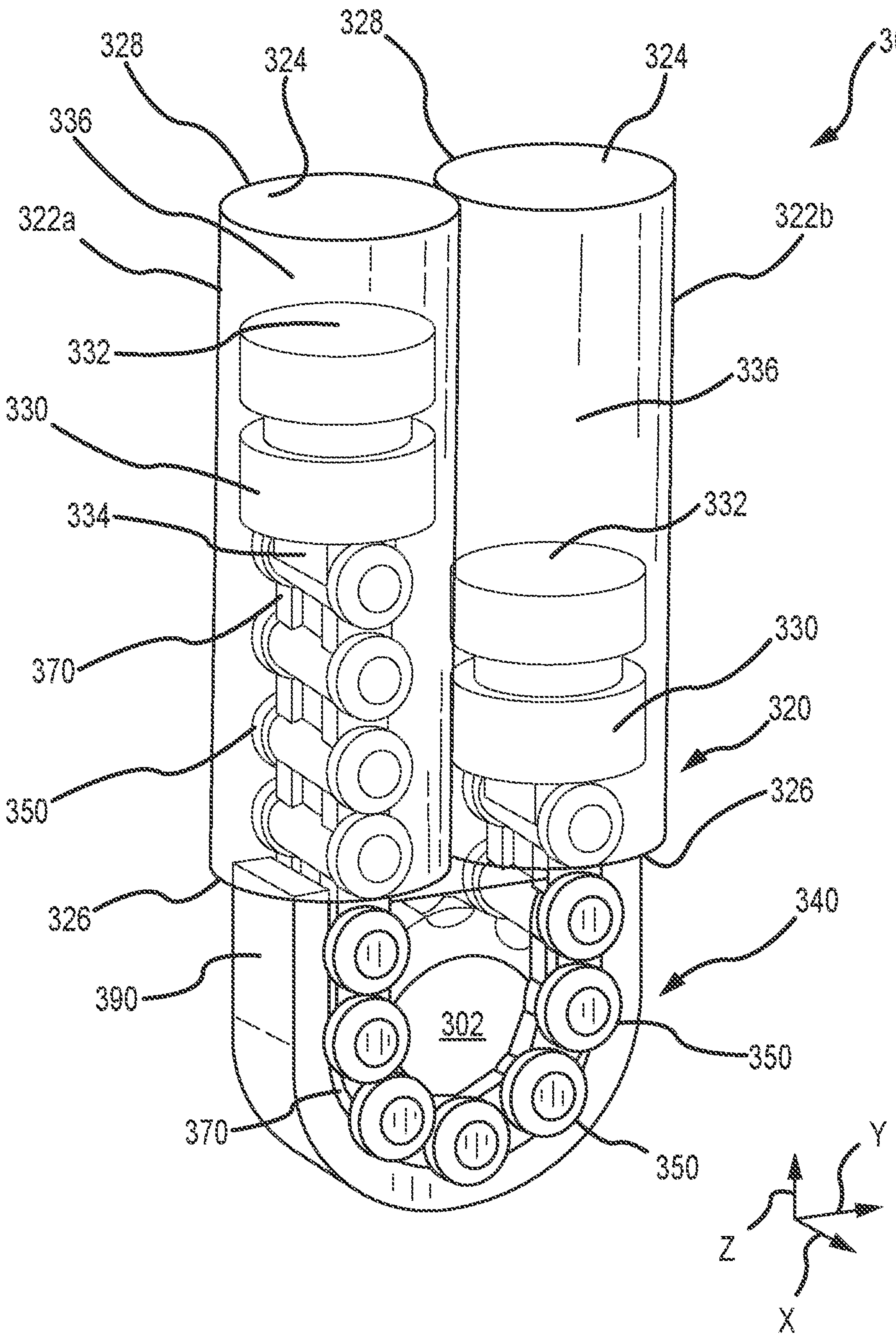
FIG.4A



328
324
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Y
Z
X

FIG.4B

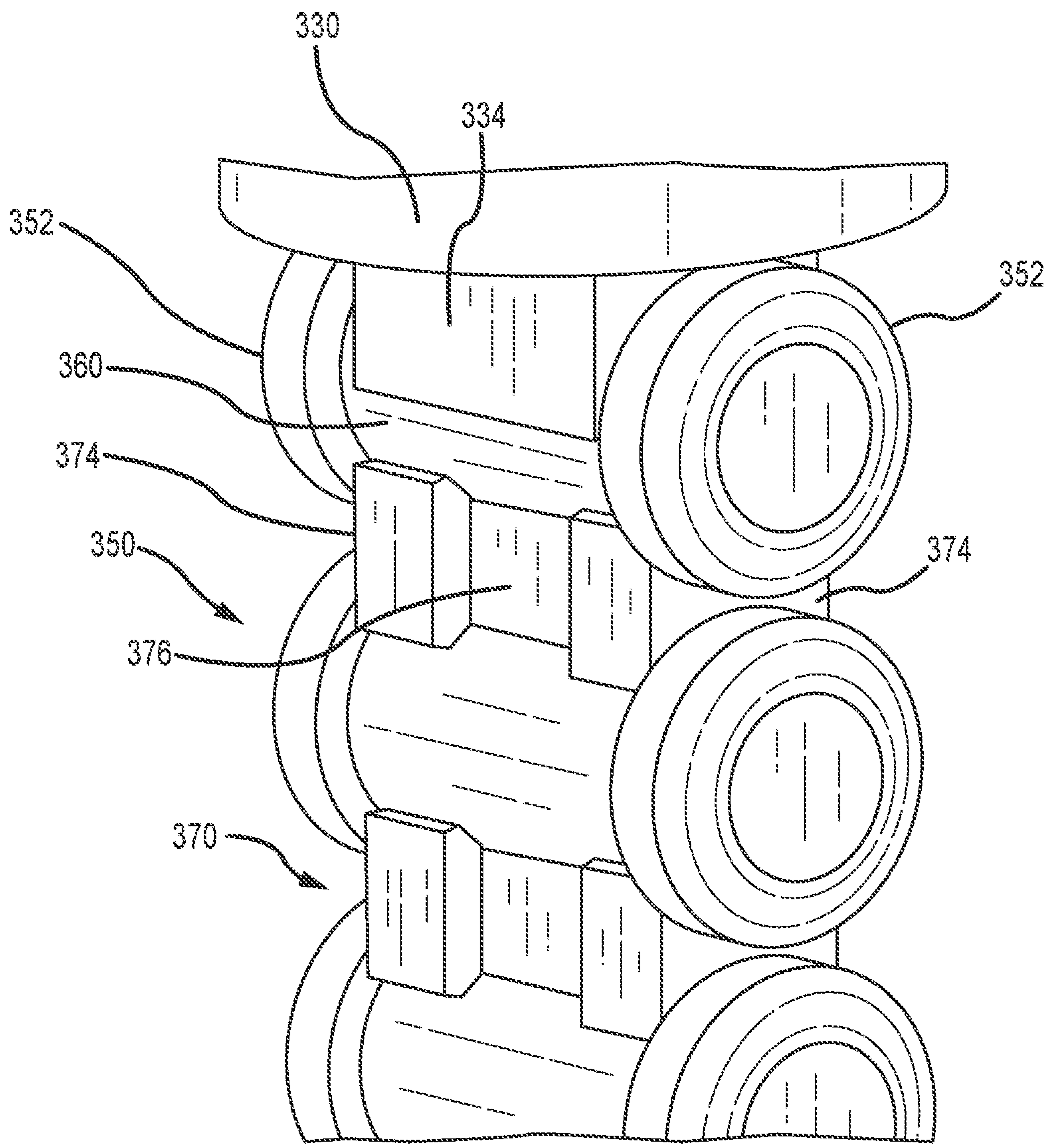

FIG.5

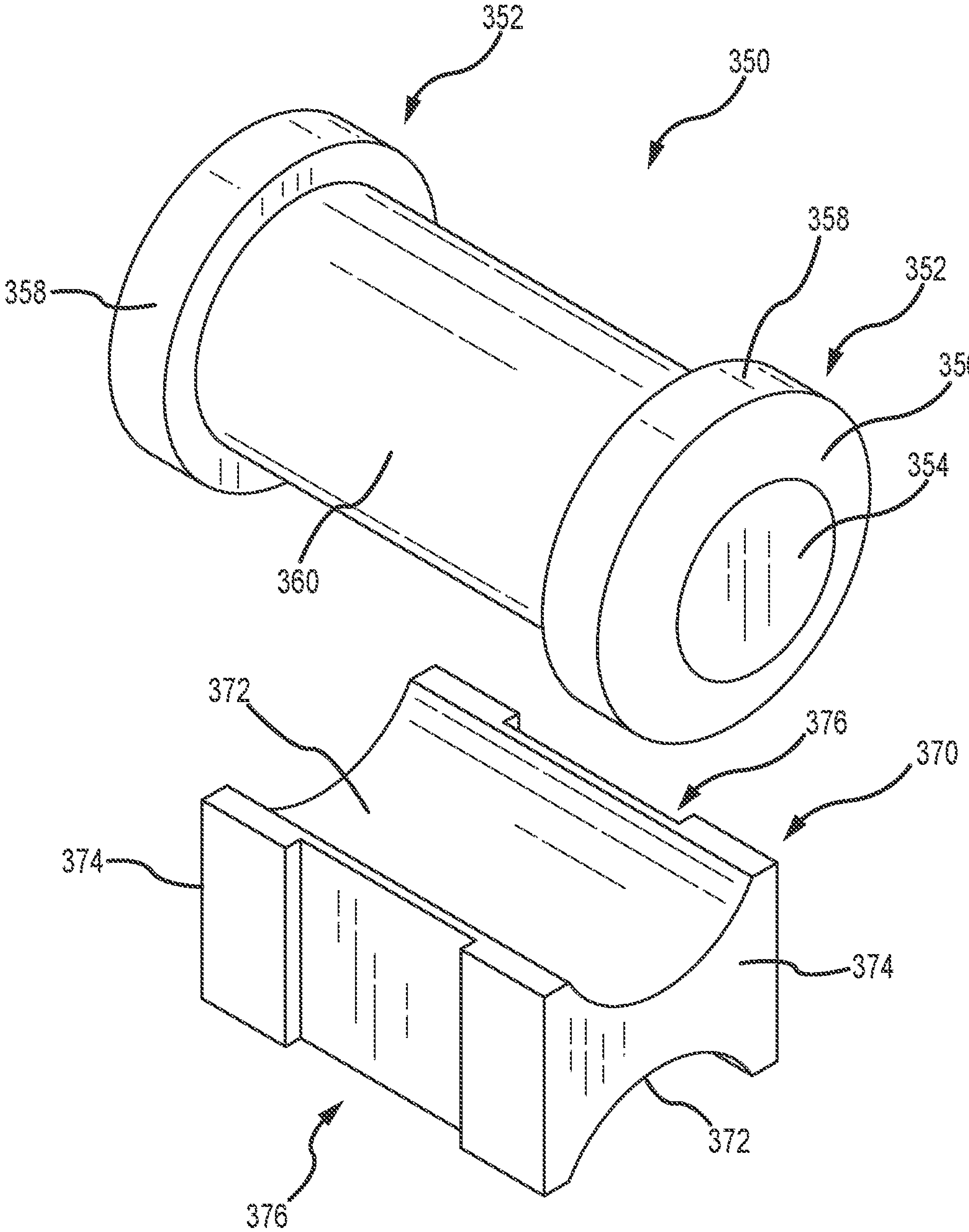

FIG.5A

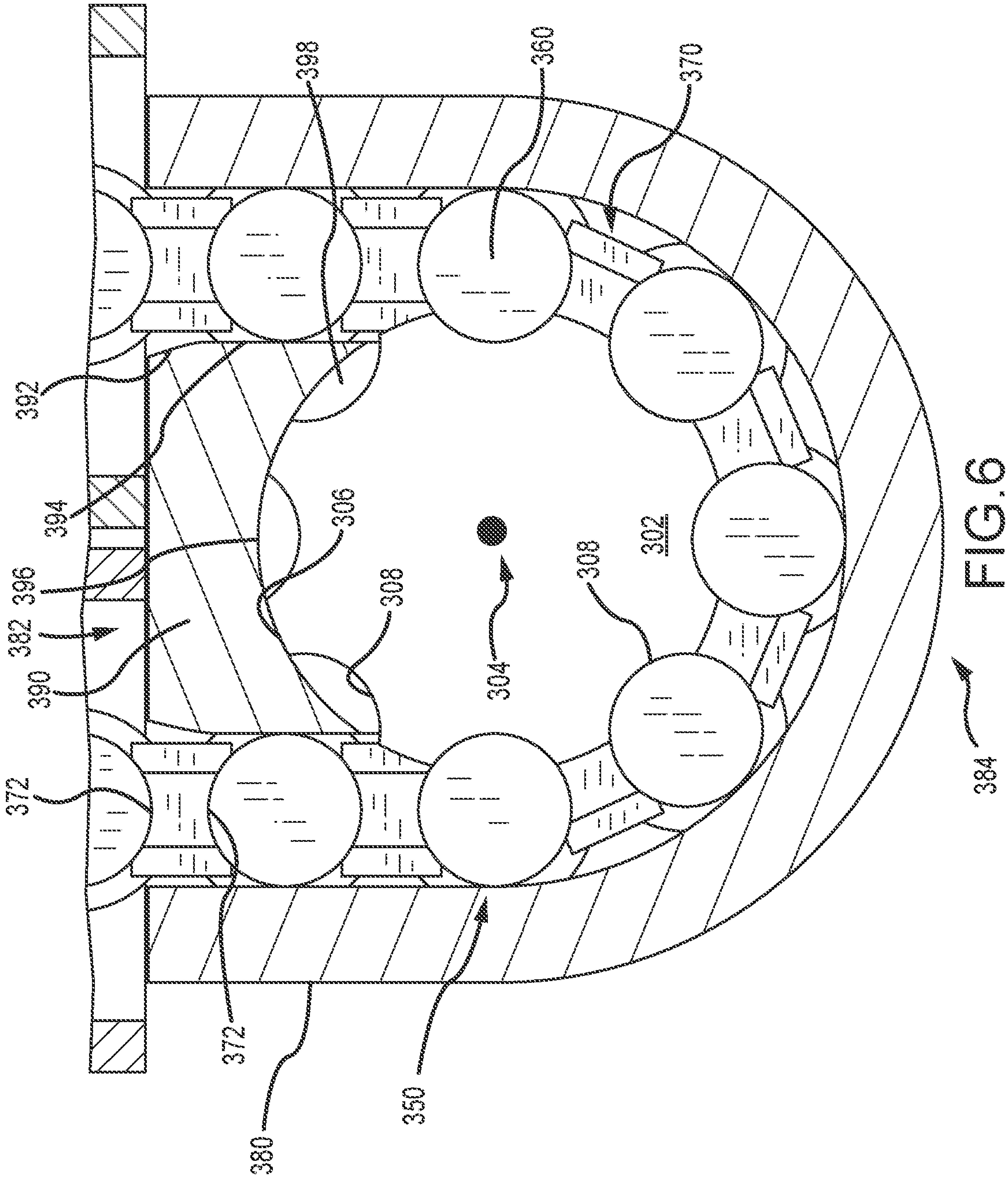
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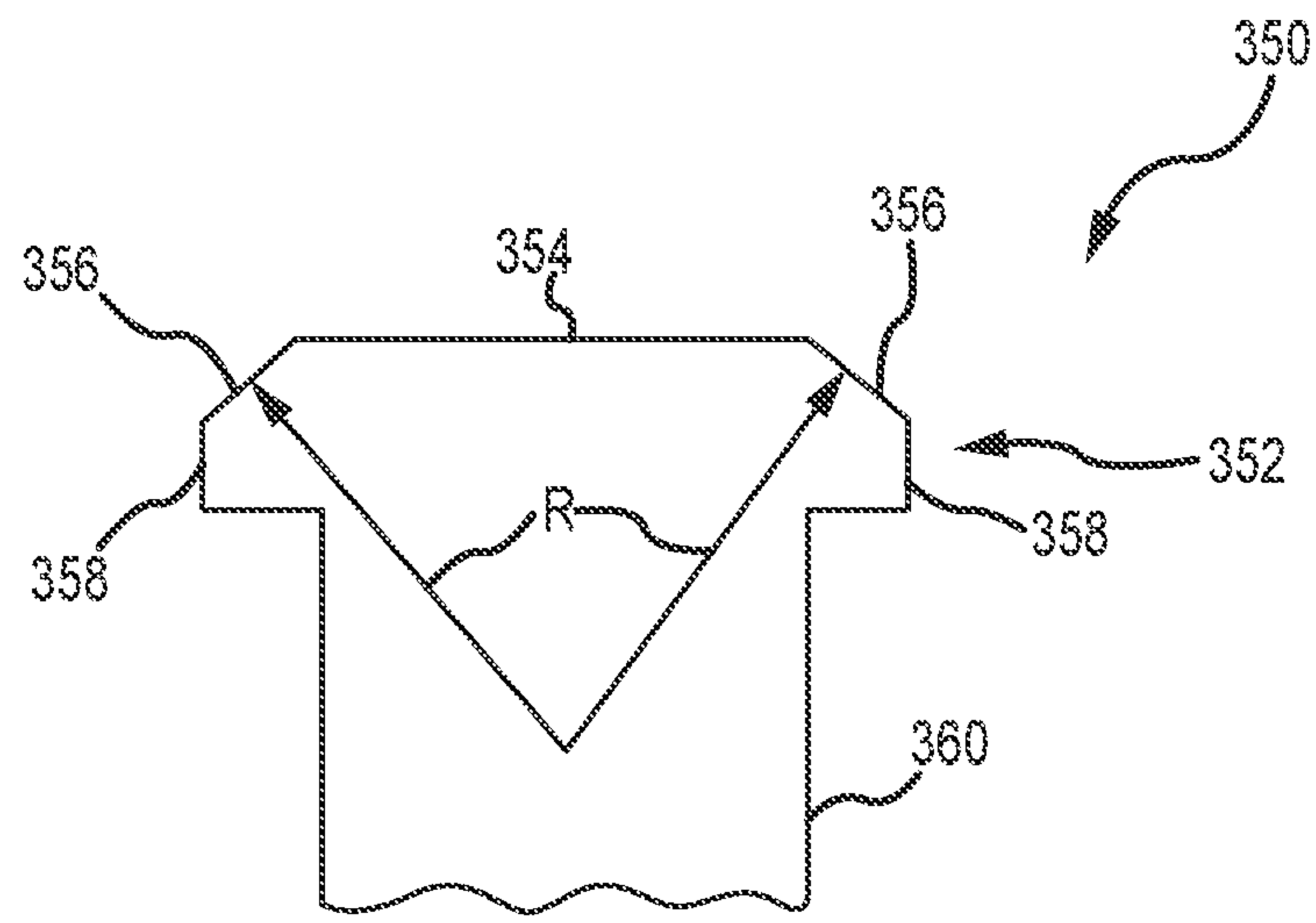
FIG.6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358
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FIG.7A

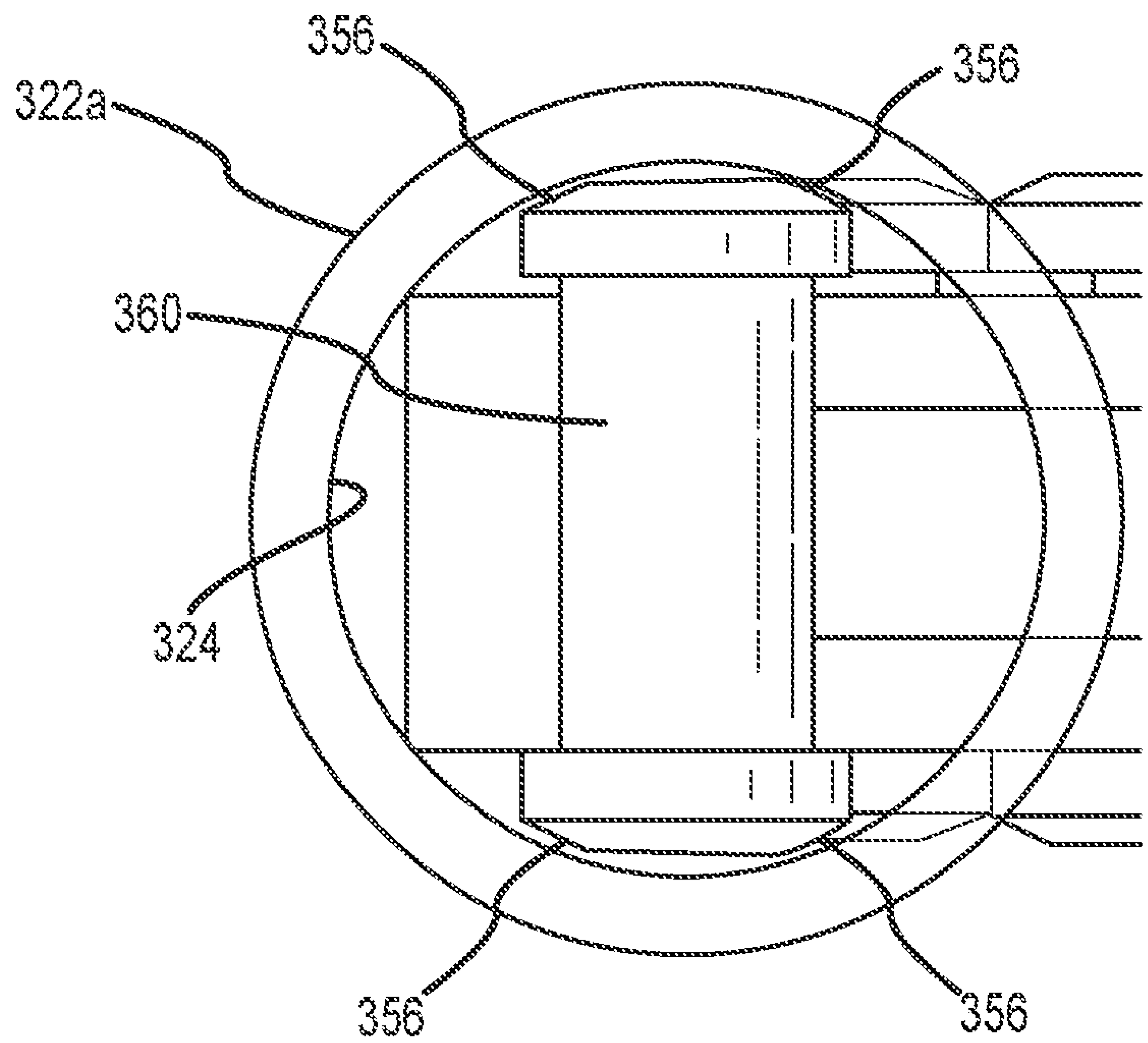
356
356
322a
360
324
356
356

FIG.7B

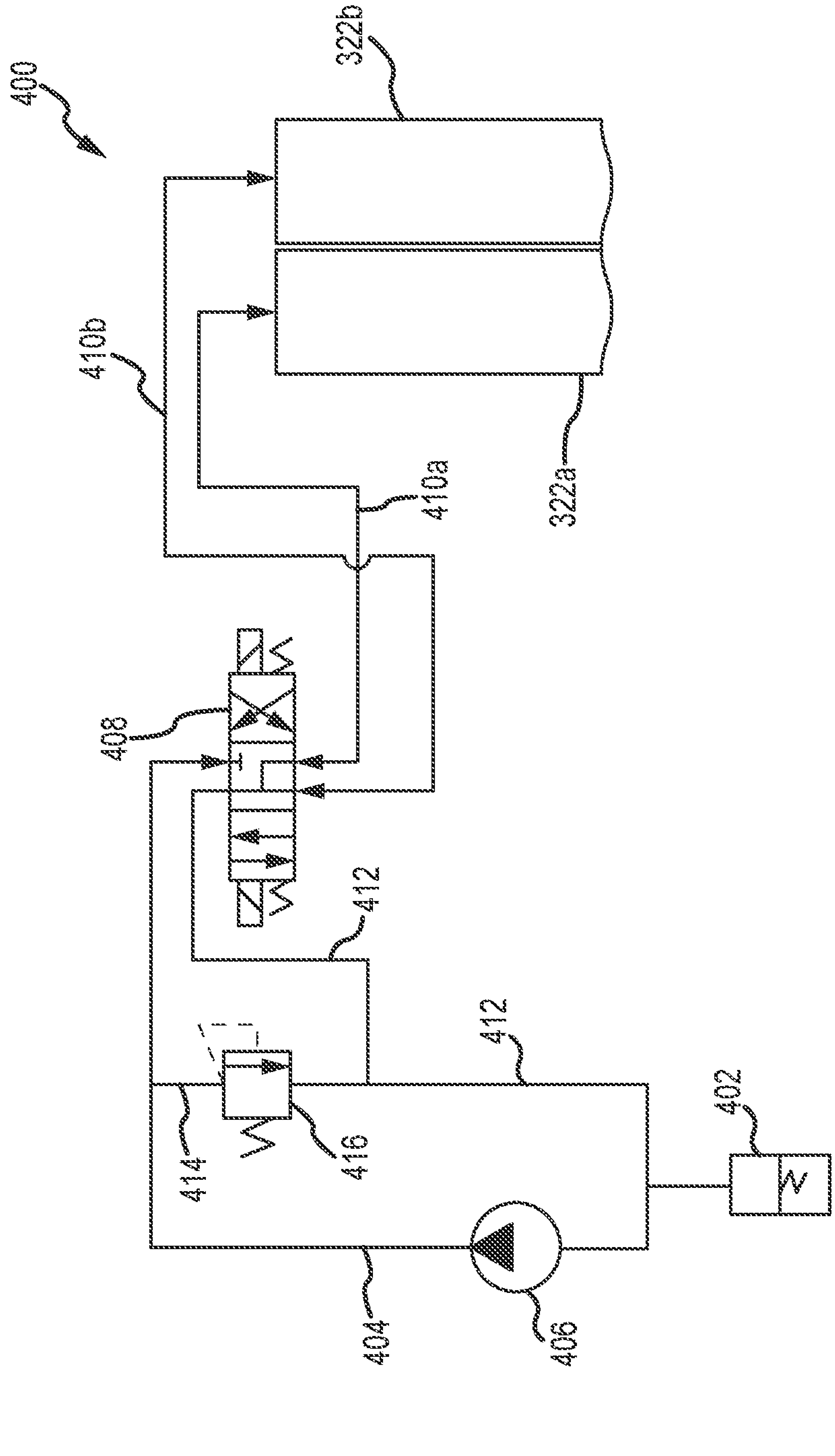

FIG.8

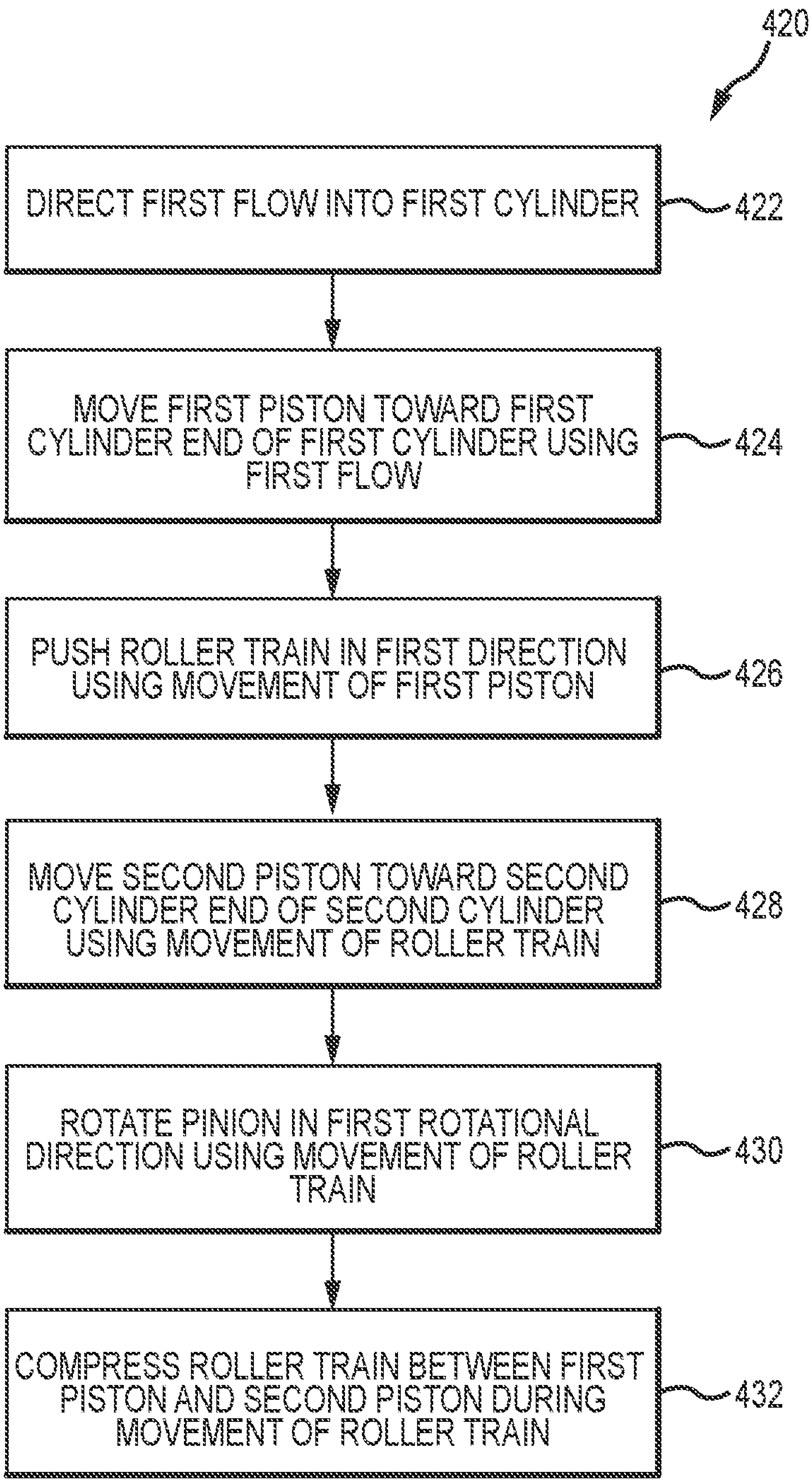
420
DIRECT FIRST FLOW INTO FIRST CYLINDER
422
MOVE FIRST PISTON TOWARD FIRST CYLINDER END OF FIRST CYLINDER USING FIRST FLOW
424
PUSH ROLLER TRAIN IN FIRST DIRECTION USING MOVEMENT OF FIRST PISTON
426
MOVE SECOND PISTON TOWARD SECOND CYLINDER END OF SECOND CYLINDER USING MOVEMENT OF ROLLER TRAIN
428
ROTATE PINION IN FIRST ROTATIONAL DIRECTION USING MOVEMENT OF ROLLER TRAIN
430
COMPRESS ROLLER TRAIN BETWEEN FIRST PISTON AND SECOND PISTON DURING MOVEMENT OF ROLLER TRAIN
432

FIG.9

COMPACT AIRCRAFT ACTUATOR SYSTEM

FIELD

The present disclosure generally relates to the field of aircraft and, more particularly, to an aircraft actuation system having reduced space requirements.

BACKGROUND

Aircraft may utilize both nose landing gear, typically aftly-disposed port-side landing gear, and typically aftly-disposed starboard-side landing gear. The landing gear may support the aircraft when not flying, allowing the aircraft to taxi, takeoff, and land. The nose landing gear may also be used to steer the aircraft. Conventional linear rack & pinion actuators are relatively simple and cost effective, but they have a fairly long cylinder overall length, especially for steering applications that require steering angles in excess of approximately +/−60 degrees. Attempting to package such an actuator to fit within an available aircraft installation envelope may be extremely difficult.

SUMMARY

An aircraft actuation system is presented herein. Both the configuration of such an aircraft actuation system and the operation of such an aircraft actuation system are within the scope of this Summary. This aircraft actuation system may be used for any appropriate application, including to exert an actuation force to rotate aircraft nose landing gear (e.g., to steer an associated aircraft), to exert an actuation force to deploy aircraft landing gear, to exert an actuation force to retract aircraft landing gear, to exert an actuation force to open a door, to exert an actuation force to close a door, or the like.

One aspect is embodied by an aircraft actuation system that includes a pinion, a first cylinder, a first piston that is movably disposed within the first cylinder, a second cylinder, a second piston that is movably disposed within the second cylinder, and a transfer member (e.g., a roller train) that is interconnected with each of the first piston and the second piston. At least part of the transfer member is disposed out of each of the first and second cylinders and is engaged with the pinion. Movement of the first piston and the second piston within the first cylinder and the second cylinder, respectively, moves the transfer member to rotate the pinion. Rotation of the pinion may be used as an actuation force for an aircraft component. The first and second cylinders may be disposed in noncollinear relation with one another, including where the first and second cylinders are disposed in parallel relation to one another and occupy a common position in a length dimension for the aircraft actuation system.

Another aspect is embodied by a method of operating an aircraft actuation system that includes a first cylinder and a second cylinder. The first and second cylinders each have a first cylinder end and an oppositely disposed second cylinder end. A first flow may be directed into the first cylinder to move the first piston within the first cylinder toward its corresponding first cylinder end in response to this first flow. A roller train may be pushed in a first direction in response to this movement of the first piston by the first flow. This roller train extends between the first and second cylinders and engages a pinion of the aircraft actuation system. The piston within the second cylinder is moved toward its corresponding second cylinder end in response to the movement of the roller train in the first direction (e.g., the pistons within the first and second cylinders may be characterized as moving in opposite directions). The pinion is rotated in a first rotational direction using the movement of the roller train in the first direction. The roller train is compressed between the first piston and the second piston by using the first flow to push the first piston within the first cylinder and by pressurized fluid acting on the second piston within the second cylinder to oppose movement of the second piston toward its corresponding second cylinder end.

Various aspects of the present disclosure are also addressed by the following examples and in the noted combinations:

1. An aircraft actuation system comprising:
   - a pinion;
   - a first cylinder;
   - a first piston movably disposed within said first cylinder;
   - a second cylinder disposed in non-collinear relation with said first cylinder;
   - a second piston movably disposed within said second cylinder;
   - a transfer member interconnected with each of said first piston and said second piston, wherein at least part of said transfer member is disposed out of each of said first and second cylinders and is engaged with said pinion;
   - wherein movement of said first piston and said second piston within said first cylinder and said second cylinder, respectively, moves said transfer member to rotate said pinion.
2. The aircraft actuation system of example 1, wherein said first cylinder is parallel with said second cylinder.
3. The aircraft actuation system of example 2, wherein a reference axis located between said first cylinder and said second cylinder defines a longitudinal dimension for said aircraft actuation system, wherein said first cylinder and said second cylinder are disposed at a common position in said longitudinal dimension.
4. The aircraft actuation system of example 1, wherein a reference axis located between said first cylinder and said second cylinder defines a longitudinal dimension for said aircraft actuation system, wherein at least one of said first cylinder and said second cylinder is disposed at an angle relative to said reference axis.
5. The aircraft actuation system of example 4, wherein an included angle between said first cylinder and said second cylinder is less than 180°.
6. The aircraft actuation system of any of examples 1-5, wherein said transfer member is retained in compression between said first piston and said second piston.
7. The aircraft actuation system of any of examples 1-6, wherein said transfer member comprises a roller train comprising a plurality of rollers disposed in spaced relation to one another.
8. The aircraft actuation system of any of examples 1-6, wherein said transfer member comprises a plurality of rollers and a plurality of shoes, wherein each roller of said plurality of rollers is disposed in spaced relation to every other said roller of said plurality of rollers, wherein each shoe of said plurality of shoes is disposed in spaced relation to every other said shoe of said plurality of shoes, and wherein a different single said shoe is disposed between each adjacent pair of said rollers of said plurality of rollers.
9. The aircraft actuation system of example 8, wherein each said roller of said plurality of rollers comprises a central body.

10. The aircraft actuation system of example 9, wherein said central body of each said roller of said plurality of rollers is engaged with an at least generally complementary-shaped curved surface of each said shoe that is engaged with said roller.

11. The aircraft actuation system of any of examples 9-10, wherein said central body of each said roller of said plurality of rollers is engageable with an at least generally complementary-shaped pocket on an outer perimeter of said pinion.

12. The aircraft actuation system of any of examples 9-11, wherein each said roller of said plurality of rollers comprises a pair of heads disposed at opposite ends of said central body, wherein each head of said pair of heads has a larger outer diameter than an outer diameter of its corresponding said central body.

13. The aircraft actuation system of example 12, wherein each said head of each said roller comprises a flat end surface and a curved transition surface defined by a radius that is slightly less than a radius of an inner surface of each of said first cylinder and said second cylinder.

14. The aircraft actuation system of example 13, wherein contact between each said head of each said roller of said plurality of rollers and said inner surface of each of said first cylinder and said second cylinder is limited to said curved transition surface.

15. The aircraft actuation system of any of examples 12-14, wherein said pair of heads of each said roller of said plurality of rollers constrains movement in a first dimension.

16. The aircraft actuation system of any of examples 1-15, further comprising:

an outer race extending from a first end of said first cylinder, around a portion of said pinion and spaced from said pinion, and to a first end of said second cylinder.

17. The aircraft actuation system of example 16, wherein said outer race is at least substantially U-shaped.

18. The aircraft actuation system of any of examples 16-17, further comprising:

a guide disposed at least generally at said first end of each of said first cylinder and said second cylinder, disposed within an open end of said outer race and spaced inwardly of said outer race, and disposed between said pinion and each of said first cylinder and said second cylinder.

19. The aircraft actuation system of example 18, wherein said guide maintains an orientation of each said roller of said plurality of rollers prior to entering a space between said outer race and said pinion.

20. An aircraft comprising landing gear and the aircraft actuation system of any of examples 1-19, wherein rotation of said pinion actuates said landing gear.

21. The aircraft of example 20, wherein said actuation of said landing gear comprises steering said landing gear.

22. The aircraft of example 20, wherein said actuation of said landing gear comprises moving said landing gear between deployed and retracted positions.

23. A method of operating an aircraft actuation system comprising a first cylinder and a second cylinder, wherein each of said first cylinder and said second cylinder has a first cylinder end and an oppositely disposed second cylinder end, said method comprising:

directing a first flow into said first cylinder;

moving a first piston within said first cylinder toward said first cylinder end of said first cylinder in response to said directing a first flow step;

pushing a roller train in a first direction in response to said moving a first piston step by said first flow, wherein said roller train extends between said first and second cylinders and is engaged with a pinion of said aircraft actuation system throughout said pushing a roller train in a first direction step;

moving a second piston within said second cylinder toward said second cylinder end of said second cylinder in response to said pushing a roller train in a first direction step and against a pressurized fluid within said second cylinder between said second piston and said second cylinder end of said second cylinder;

rotating said pinion in a first rotational direction using said pushing a roller train in a first direction step; and

compressing said roller train between said first piston and said second piston using each of said pushing a roller train in a first direction step and said pressurized fluid within second cylinder.

24. The method of example 23, wherein said compressing said roller train step comprises compressing a plurality of rollers and a plurality of shoes between said first piston and said second piston.

25. The method of example 24, wherein each roller of said plurality of rollers is disposed in spaced relation to every other said roller of said plurality of rollers, wherein each shoe of said plurality of shoes is disposed in spaced relation to every other said shoe of said plurality of shoes, and wherein a different single said shoe is disposed between each adjacent pair of said rollers of said plurality of rollers.

26. The method of example 25, wherein contact between a first roller of said plurality of rollers and each of a first shoe and a second shoe of said plurality of shoes is maintained by said compressing said roller train step.

27. The method of any of examples 23-27, wherein said roller train extends into each of said first cylinder and said second cylinder, said method further comprising:

precluding said roller train from buckling within said first cylinder; and

precluding said roller train from buckling within said second cylinder.

28. The method of any of examples 23-27, wherein said aircraft actuation system further comprises an outer race, said method further comprising:

precluding said roller train from buckling upon exiting said first cylinder through its said first cylinder end and prior to entering a space between said outer race and said pinion.

29. The method of example 28, further comprising:

precluding said roller train from buckling upon exiting said space between said outer race and said pinion and prior to entering said second cylinder through its said first cylinder end.

30. The method of any of examples 23-29, further comprising:

directing a second flow into said second cylinder;

moving said second piston within said second cylinder and toward said first cylinder end of said second cylinder in response to said directing a second flow step;

pushing said roller train in a second direction in response to said moving said second piston step by said second flow, wherein said roller train is engaged with said pinion throughout said pushing said roller train in a second direction step;

moving said first piston within said first cylinder toward said second cylinder end of said first cylinder in response to said pushing said roller train in a second direction step and against a pressurized fluid within said first cylinder between said first piston and said second cylinder end of said first cylinder;

rotating said pinion in a second rotational direction using said pushing said roller train in a second direction step; and

compressing said roller train between said first piston and said second piston using each of said pushing said roller train in a second direction step and said pressurized fluid within first cylinder.

31. The method of example 30, further comprising:

providing a first actuation of an aircraft component in response to said rotating said pinion in a first rotational direction step; and

providing a second actuation of said aircraft component in response to said rotating said pinion in a second rotational direction step, wherein a result of said first actuation is different than a result of from said second actuation.

32. The method of any of examples 23-29, further comprising:

providing a first actuation of an aircraft component in response to said rotating said pinion in a first rotational direction step.

BRIEF DESCRIPTION OF THE DRAWINGS

The subject matter of the present disclosure is particularly pointed out and distinctly claimed in the concluding portion of the specification. An understanding of the present disclosure may be further facilitated by referring to the following detailed description and claims in connection with the following drawings. While the drawings illustrate various embodiments employing the principles described herein, the drawings do not limit the scope of the claims. Reference to “in accordance with various embodiments” in this Brief Description of the Drawings also applies to the corresponding discussion in the Detailed Description.

FIG. **1** illustrates an aircraft having a landing gear assembly and wheels mounted thereon, in accordance with various embodiments;

FIG. **2** illustrates mechanical components of an electro-hydraulic nose landing gear architecture, in accordance with various embodiments;

FIG. **3**A is a schematic of an aircraft actuation system that utilizes a pair of cylinders disposed in parallel relation, in accordance with various embodiments;

FIG. **3**B is a schematic of an aircraft actuation system that utilizes a pair of cylinders disposed in non-parallel relation, in accordance with various embodiments;

FIG. **4**A illustrates an aircraft actuation system that utilizes a roller train that extends between a pair of cylinders to rotate a pinion, in accordance with various embodiments;

FIG. **4**B is a perspective view of the aircraft actuation system of FIG. **4**A, in accordance with various embodiments;

FIG. **5** is an enlarged, perspective view of a portion of the roller train used by the aircraft actuation system of FIG. **4**A, in accordance with various embodiments;

FIG. **5**A is an exploded, perspective view of a portion of the roller train used by the aircraft actuation system of FIG. **4**A, in accordance with various embodiments;

FIG. **6** is an enlarged, cutaway view of a roller guide, pinion, and track used by the aircraft actuation system of FIG. **4**A, in accordance with various embodiments;

FIG. **7**A is an enlarged view of one of the heads of one of the rollers used by the roller train for the aircraft actuation system of FIG. **4**A, in accordance with various embodiments;

FIG. **7**B is an enlarged view of the interface between one of the rollers used by the roller train for the aircraft actuation system of FIG. **4**A and its corresponding cylinder, in accordance with various embodiments;

FIG. **8** is a schematic of a hydraulic system that may be used to operate the aircraft actuation system of FIG. **4**A; and

FIG. **9** illustrates a protocol for operating an aircraft actuation system.

DETAILED DESCRIPTION

A representative aircraft **100** is illustrated in FIG. **1**. In accordance with various embodiments, the aircraft **100** may include one or more landing gear systems, such as, for example, a left landing gear system **102** (or port-side landing gear system), a right landing gear system **104** (or starboard-side landing gear system) and a nose landing gear system **106**. Each of the left landing gear system **102**, the right landing gear system **104** and the nose landing gear system **106** may support the aircraft **100** when not flying, allowing the aircraft **100** to taxi, takeoff and land, safely and without damage to the aircraft. In various embodiments, the left landing gear system **102** may include a left landing gear assembly **108** that includes a left wheel assembly **110**, the right landing gear system **104** may include a right landing gear assembly **112** that includes a right wheel assembly **114** and the nose landing gear system **106** may include a nose landing gear assembly **116** that includes a nose wheel assembly **118**

A representative aircraft **200** having a nose landing gear system **206** configured for retraction and stowage within an interior bay section **201** (or a nose landing gear bay) of the aircraft **200** is illustrated in FIG. **2**, in accordance with various embodiments. The nose landing gear system **206** includes a steering actuator **230**, a door actuator **232** and a retract actuator **234**. The nose landing gear system **206** may further include a downlock actuator **236** and an uplock actuator **238** which, in various embodiments, may be located internal to the retract actuator **234** or external to the retract actuator **234** and connected to a fixed structure **203** within the interior bay section **201**. The steering actuator **230** is connected to a steering collar **215** that is itself connected to a nose landing gear assembly **216** and configured to steer the nose landing gear system **206**. The steering actuator **230** comprises an electric motor **240**, a gear box **242** configured to transmit power provided by the electric motor **240** to the steering collar **215** and a clutch **244**. In various embodiments, the combination of the electric motor **240**, the gear box **242** and the clutch **244** comprises an electromechanical actuator **248** connected to the steering collar **215** and configured to steer the aircraft **200**. In various embodiments, the steering actuator **230** may also include a hydraulic pump **241** operably coupled to the electric motor **240**. A power cable **247** provides electrical power from a power source **249** to the electric motor **240**. In various embodiments, the power source **249** is disposed locally within the interior bay section **201** or is provided by a centralized electrical power system external to the interior bay section **201**.

The door actuator **232** of the aircraft **200** is connected to a door assembly **243** and configured to open and close a fairing door **245** of the door assembly **243** in order to provide access to the interior bay section **201** of the aircraft **200** for the nose landing gear system **206** to be stored when retracted. In various embodiments, the fairing door **245** may be slaved to the nose landing gear assembly **216** or to one or more other components of the nose landing gear system **206**, obviating a need for the door actuator **232**. The retract actuator **234** is connected to the nose landing gear assembly **216** and configured to raise and lower the nose landing gear assembly **216** into and out of, respectively, the interior bay section **201** of the aircraft **200**.

An aircraft actuation system that may be used to steer aircraft nose landing gear (e.g., nose landing gear system **106** of FIG. **1**; nose landing gear system **206** of FIG. **2**), for instance by rotating a strut or strut assembly of such landing gear, is illustrated in FIG. **3**A and is identified by reference numeral **270***a*. However, the aircraft actuation system **270***a* may also be used for other aircraft applications, such as opening/closing aircraft doors, actuation of aircraft landing gear (to deploy and retract aircraft landing gear), and the like.

The aircraft actuation system **270***a* includes a pinion **272** that is rotatable about an axis **274**. This pinion **272** may be directly connected or indirectly interconnected (e.g., via one or more gears, belts, cables, and/or chains) with another aircraft component, such that rotation of the pinion **272** actuates this aircraft component. The aircraft actuation system **270***a* further includes what may be characterized as a pinion actuator **280**—a combination of components for rotating the pinion **272** about its rotational axis **274**. The pinion actuator **280** includes a pair of cylinders **282***a*, **282***b* that each have a piston **288** movably disposed therein. Each cylinder **282***a*, **282***b* has a corresponding cylinder longitudinal axis **284***a*, **284***b*, with these axes **284***a*, **284***b* being disposed in parallel relation to one another and furthermore in parallel relation to a reference axis **276** that extends through the rotational axis **274** of the pinion **272** and that is disposed between these longitudinal axes **284***a*, **284***b*. The reference axis **276** may be characterized as defining a length dimension of the aircraft actuation system **270***a*. In this regard, the cylinders **282***a*, **282***b* occupy the same position in this longitudinal dimension (e.g., their respective ends **286***a* are disposed in opposing relation, as are their respective ends **286***b*).

Each piston **288** may be moved toward a cylinder end **286***a* of its corresponding cylinder **282***a*, **282***b*, or toward a cylinder end **286***b* of its corresponding cylinder **282***a*, **282***b*. When the piston **288** in the cylinder **282***a* is moved toward its cylinder end **286***a*, the piston **288** in the other cylinder **282***b* is moved toward its cylinder end **286***b*. Similarly, when the piston **288** in the cylinder **282***b* is moved toward its cylinder end **286***a*, the piston **288** in the other cylinder **282***a* is moved toward its cylinder end **286***b*. As such, each piston **288** moves/reciprocates in its corresponding cylinder **282***a*, **282***b* in the direction indicated by the double-headed arrows A and B, respectively, in FIG. **3**A (e.g., in alternating relation relative to the two different cylinders **282***a*, **282***b*).

What may be characterized as a transfer member **294** extends from the piston **288** in the cylinder **282***a*, to the pinion **272** where it engages a portion of an outer perimeter of the pinion **272**, and to the piston **288** disposed in the other cylinder **284***b*. The transfer member **294** may be characterized as being part of the pinion actuator **280**. Movement of the transfer member **294**, by corresponding movement of the pistons **288** in the cylinders **282***a*, **282***b*, will rotate the pinion **272** about its rotational axis **274** via its engagement with the pinion **272**. Any appropriate interface may be used between the transfer member **294** and the pinion **272**, such that movement of the transfer member **294** by corresponding movements of the noted pistons **288** will rotate the pinion **272**.

The aircraft actuation system **270***a* may be configured such that the transfer member **294** is maintained in compression between the two pistons **288** during operation of the aircraft actuation system **270***a* (e.g., in accord with the aircraft actuation system **300** that will be discussed in more detail below in relation to FIGS. **4**A-**8**). For instance, hydraulic fluid (or more generally a flow) may be directed into a chamber **292** of the cylinder **282***a* to move its piston **288** in the direction of its cylinder end **286***a*, which through the transfer member **294** (via movement in what may be characterized as a first direction) may be used to move the piston **288** in the cylinder **282***b* in the direction of its cylinder end **286***b* and to rotate the pinion **272** about its rotational axis **274** in a first rotational direction. This movement of the piston **288** in the cylinder **282***b* in the direction of its cylinder end **286***b* may be resisted by maintaining at least a certain pressure within a chamber **292** of the cylinder **282***b* (via pressurized fluid, for instance fluid at a pressure within a range of 50-100 psi). The chamber **292** of each cylinder **282***a*, **282***b* is between its corresponding piston **288** and its corresponding cylinder end **286***b*. Conversely, hydraulic fluid may be directed into the chamber **292** of the cylinder **282***b* to move its piston **288** in the direction of its cylinder end **286***a*, which through the transfer member **294** (via movement in what may be characterized as a second direction that is opposite the above-noted first direction) may be used to move the piston **288** in the cylinder **282***a* in the direction of its cylinder end **286***b* and to rotate the pinion **272** about its rotational axis **274** in a second rotational direction (opposite to the above-noted first rotational direction). This movement of the piston **288** in the cylinder **282***a* in the direction of its cylinder end **286***b* may be resisted by maintaining at least a certain pressure within the chamber **292** of the cylinder **282***a* (via pressurized fluid, for instance fluid at a pressure within a range of 50-100 psi).

The above-described pinion actuator **280** may be characterized as a "U-shaped rack" for rotating the pinion **272**. This U-shaped rack is collectively defined by the above-noted cylinders **282***a*, **282***b*, along with the transfer member **294** that extends between the pistons **288** in each of these cylinders **282***a*, **282***b* and about a portion of the outer perimeter of the pinion **272**. This U-shaped configuration reduces space requirements for the aircraft actuation system **270***a*, which may be beneficial in one or more instances.

A variation of the aircraft actuation system **270***a* of FIG. **3**A is presented in FIG. **3**B and is identified by reference numeral **270***b*. Corresponding components between the aircraft actuation system **270***a* (FIG. **3**A) and the aircraft actuation system **270***b* (FIG. **3**B) are identified by the same reference numerals, and unless otherwise noted to the contrary herein the foregoing description remains equally applicable to these corresponding components of the aircraft actuation system **270***b* of FIG. **3**B. The primary difference between the aircraft actuation system **270***a* of FIG. **3**A and the aircraft actuation system **270***b* of FIG. **3**B is the orientation of the cylinders **282***a*, **282***b* in that the cylinders **282***a*, **282***b* are disposed in non-parallel relation to one another. The cylinder longitudinal axis **284***a*' of the cylinder **282***a* is disposed at an angle **296** relative to the reference axis **276** that again extends through the rotational axis **274** of the pinion **272**, that is disposed between the cylinders **282***a*, **282***b*, and that defines a length dimension of the aircraft actuation system **270***b*. The cylinder longitudinal axis **284***b*' of the cylinder **282***b* is disposed at an angle **298** relative to the reference axis **276**. Each of the angles **296**, **298** may be 0° or greater and may be up to 90°, although the sum of the angles **296**, **298** should be less than 180°. Although the orientation of the cylinder **282***a* may be the mirror image of the cylinder **284***b* relative to the reference axis **276** (e.g., the magnitudes of the angles **296**, **298** may be of equal values), such need not the case (e.g., the magnitudes of the angles **296**, **298** may be different values). One of the cylinders **282***a* could be parallel with the reference axis **276**, and the other of the cylinders **282***a*, **282***b* could be disposed at a 90° angle relative to the reference axis **276**.

An aircraft actuation system (including individual components thereof) that may be used to steer aircraft nose landing gear (e.g., nose landing gear system **106** of FIG. **1**; nose landing gear system **206** of FIG. **2**), for instance by rotating a strut or strut assembly of such landing gear, is illustrated in FIGS. **4**A-**7**B and is identified by reference numeral **300**. However, the aircraft actuation system **300** may also be used for other aircraft applications, such as opening/closing aircraft doors, actuation of aircraft landing gear (to deploy and retract aircraft landing gear), and the like. Although the configuration of the aircraft actuation system **300** is illustrated as being at least generally in accord with the aircraft actuation system **270***a* of FIG. **3**A, the aircraft actuation system **300** may also be modified to be in accord with the aircraft actuation system **270***b* of FIG. **3**B. With regard to a steering application for aircraft nose landing gear, it should be appreciated that the electromechanical nose wheel steering actuator described above with regard to FIG. **2** would be replaced by a hydro-mechanical actuator, for instance in accord with the aircraft actuation system **300** (converting hydraulic power to mechanical power with or without a gearbox at its output), which may (in various embodiments) be driven by a centralized hydraulic system, a local electric motor-driven pump (powerpack) system, or an electric motor-driven pump integrated directly into the steering actuator.

As shown in FIGS. **4**A and **4**B, the aircraft actuation system **300** includes a pinion **302** that is rotatable about an axis **304**. This pinion **302** may be directly connected or indirectly interconnected (e.g., via one or more gears, belts, cables, and/or chains) with another aircraft component, such that rotation of the pinion **302** actuates this aircraft component. In any case, the pinion **302** (as shown in greater detail in FIG. **6**) includes an outer perimeter **306** having a plurality of pockets or recesses **308** that are spaced about the rotational axis **304** (e.g., in equally-spaced relation).

The aircraft actuation system **300** further includes what may be characterized as a pinion actuator **320**—a combination of components for rotating the pinion **302** about its rotational axis **304**. The pinion actuator **320** includes a pair of cylinders **322***a*, **322***b* (presented in transparency in FIGS. **4**A-**4**B) that each have a piston **330** movably disposed therein and that each includes an inner cylindrical surface **324**. The cylinders **322***a*, **322***b* are disposed in parallel relation to one another. Each piston **330** may be moved toward a cylinder end **326** of its corresponding cylinder **322***a*, **322***b*, or toward a cylinder end **328** of its corresponding cylinder **322***a*, **322***b*. In response to the piston **330** in the cylinder **322***a* being moved toward its cylinder end **326** in a manner that will be discussed in more detail below, the piston **330** in the other cylinder **322***b* moves toward its cylinder end **328**. Similarly, in response to the piston **330** in the cylinder **322***b* moving toward its cylinder end **326**, the piston **330** in the other cylinder **322***a* is moved toward its cylinder end **328**. As such, each piston **330** moves/reciprocates in its corresponding cylinder **322***a*, **322***b* along an axial path (including in alternating relation).

A chamber **336** is defined in each cylinder **322***a*, **322***b* between a face **332** of its corresponding piston **330** and its corresponding cylinder end **328**. A roller interface **334** is incorporated by each piston **330** and is disposed opposite its corresponding piston face **332** (e.g., the roller interface **334** and the piston face **332** of each piston **330** are spaced along a length dimension of its corresponding cylinder **332***a*, **332***b*).

The aircraft actuation system **300** includes a transfer member (to engage/rotate the pinion **302**) in the form of a roller train **340**. The roller train **340** may be characterized as being part of the pinion actuator **320**. The roller train **340** includes a plurality of rollers **350** that are spaced along a length dimension of the roller train **340**, with a single spacer or shoe **370** being disposed between each adjacent pair of rollers **350**. A roller **350** at one end of the roller train **340** is engaged by the roller interface **334** of the piston **330** in the cylinder **322***a*, while a roller **350** at the opposite end of the roller train **340** is engaged by the roller interface **334** of the piston **330** and the other cylinder **322***b*. As will be discussed in more detail below, the roller train **340** is maintained in compression between the pistons **330** within the cylinders **322***a*, **322***b*.

Each roller **350** includes a pair of heads **352** that are spaced along a length dimension of the corresponding roller **350**. A central body **360** extends between the pair of heads **352** of each roller **350**. The outer perimeter of the central body **360** may be cylindrical, and may have a smaller outer diameter than an outer diameter of heads **352**. In any case, the above-noted roller interface **334** of each piston **330** may be correspondingly-shaped with the central body **360** of the roller **350** at the corresponding end of the roller train **340** (the roller interface **334** of each piton **330** may engage the central body **360** of the roller **350** at the corresponding end of the roller train **340**).

As shown in FIG. **5**A, the head **352** of each roller **350** includes an end surface **354** (e.g., flat and oriented perpendicular to the length dimension of the corresponding roller **350**), a transition surface **356** that is curved, and a perimeter surface **358** (e.g., cylindrical). As shown in FIG. **7**A, the transition surface **356** is curved proceeding from the end surface **354** to the perimeter surface **358**, and is defined by a radius R that is slightly less than a radius of the inner surface **324** of its corresponding cylinder **322***a*, **322***b*. Oppositely-disposed portions of the transition surface **356** of each roller **350** (e.g., FIG. **7**B) may be disposed in interfacing or closely-spaced relation with the inner surface **324** of its corresponding cylinder **322***a*, **322***b*. In any case, the complementary-like shapes of the transition surface **356** of each roller **350** and the inner surface **324** of its corresponding cylinder **322***a*, **322***b* reduces the potential for misalignment of the rollers **350** within the corresponding cylinder **322***a*, **322***b*. The heads **352** of the rollers **350** (or at least for the transition surface **356**) may be coated to reduce the potential for scratching the inner surfaces **324** of the cylinders **322***a*, **322***b*. The heads **352** of the rollers **350** also could be formed from Al—Ni bronze or another similar bearing material to reduce the potential for scratching the inner surfaces **324** of the cylinders **322***a*, **322***b*.

With continued reference to FIGS. **5** and **5**A, a shoe **370** is again disposed between each adjacent pair of rollers **350** of the roller train **340**. Each shoe **370** includes a pair of curved surfaces **372** that are oppositely disposed (e.g., FIG. **6**). Each curved surface **372** may be defined by a radius that is at least substantially equal to a radius that defines the central body **360** of each roller **350**. The radius defining the curved surfaces **372** of the shoes **370** may be slightly larger than the radius defining the central body **360** of the rollers **350**. The curved surfaces **372** of the shoes and the outer perimeter of the central body **360** of the rollers **350** may be at least generally complementary-shaped.

The noted curved surfaces **372** are located between a pair of oppositely disposed ends **374** of the shoes **370** (e.g., FIGS. **5** and 5A). A recess or slot **376** is disposed between the ends **374** on at least one side of each shoe **370** (e.g., at least one a side of the shoe **370** that faces or projects toward the pinion **302**). The slots **376** provide clearance for the pinion **302** during operation of the aircraft actuation system **300**. It should be noted that the **376** slot in each shoe **370** may actually be cut deeper into the sides of the corresponding shoe **370** than as shown in one or more of the figures. Having the shoe slot **376** of at least a certain depth leaves clearance for the pinion **302** while preserving as much bearing area (shoe width) as practical for the remaining shoe length.

With reference to FIG. **6**, the aircraft actuation system **300** further includes a track or outer race **380** that is disposed beyond the outer perimeter **306** of the pinion **302** (e.g., radially outwardly of the outer perimeter **306**, relative to the rotational axis **304** of the pinion **302**). The outer race **380** may be at least generally U-shaped and includes an open end **382** that projects or faces in a direction that is away from the pinion **302**, along with an oppositely disposed closed end **384**. A guide **390** is disposed within the outer race **380**. This guide **390** is disposed at the open end **382** of the outer race **380** to facilitate retention of the rollers **350** in proper position/alignment for entry into the space between the pinion **302** and the outer race **380**.

The guide **390** includes a chamfer or first wall **392** on each of its sides to facilitate entry of the rollers **350** into the space between the guide **390** and the outer race **380**. The first walls **392** are each disposed in non-parallel relation to the corresponding portion of the outer race **380**. The spacing between each first wall **392** and its corresponding portion of the outer race **380** is progressively reduced proceeding in the direction of the closed end **384** of the outer race **380**. Each of the two sides of the guide **390** further includes a second wall **394** that is at least substantially parallel with its corresponding portion of the outer race **380**. As such, each first wall **392** and its corresponding second wall **394** on each side of the guide **390** are disposed in different orientations.

The guide **390** further includes a curved wall **396** that is disposed radially outwardly of the outer perimeter **306** of the pinion **302**. A recessed portion **398** of the guide **390** extends under the pinion **302** toward, but not to the rotational axis **304** of the pinion **302**.

The roller train **340** is maintained in compression during operation of the aircraft actuation system **300**. Hydraulic fluid (or more generally a flow) may be directed into the cylinder **322***a* to exert a force on the piston face **332** of its piston **330** to move this piston **330** in the direction of the corresponding cylinder end **326**. The opposing heads **352** of the rollers **350**, and the manner in which these heads **352** engage the inner surface **324** of the corresponding cylinder **322***a*, **322***b*, keeps the roller train **340** from buckling within the cylinders **322***a*, **322***b*. Rollers **350** exiting the cylinder **322***a* during the above-noted movement of the piston **330** in the cylinder **322***a* may be directed into the space between the pinion **302** and the outer race **380** by the guide **390**, particularly the corresponding "leading" first wall **392** of the guide **390**. The guide **390** keeps the roller train **340** from buckling from the time a given roller **350** exits the cylinder **322***a* during the above-noted movement of the piston **330** within the cylinder **322***a* and until this roller **350** is positioned within a pocket **308** on the outer perimeter **306** of the pinion **302**. When a roller **350** is positioned within a complementary-shaped pocket **308** on the outer perimeter **306** of the pinion **302**, this roller **350** will be retained between the pinion **302** and the outer race **380**, and furthermore its opposing heads **352** may be disposed on/positioned beyond corresponding surfaces of the outer race **380** and pinion **302** (e.g., the heads **352** of each roller **350** constrain movement of the rollers in the noted "x" dimension when outside the cylinders **322***a*, **322***b*).

With reference to FIGS. **4**A and **4**B, the rollers **350** are spaced along the length of the roller train **340** such that rollers **350** will be sequentially disposed in pockets **308** on the outer perimeter **306** of the pinion **302** (FIG. **6**) by the above-noted movement of the piston **330** within the cylinder **322***a* toward its cylinder end **326**, which will then rotate the pinion **302** in a first rotational direction about its rotational axis **304**. The noted movement of the piston **330** in the cylinder **322***a* will move the piston **330** in the other cylinder **322***b* in the direction of its cylinder end **328** (via the opposite end of the roller train **340** pushing piston **330** in the cylinder **322***b* toward its cylinder end **328**. Rollers **350** exiting the space between the pinion **302** and the outer race **380** are directed into the cylinder **322***b* by the guide **390**. Movement of the piston **330** in the cylinder **322***b* in the direction of its cylinder end **328** again may be resisted by maintaining at least a certain pressure within the chamber **336** of the cylinder **322***b* (e.g., via pressurized fluid, for instance fluid at a pressure within a range of 50-100 psi).

Operation of the aircraft actuation system **300** may be reversed to rotate the pinion **302** in a second rotational direction that is opposite to that described above. Summarily, hydraulic fluid (or more generally a flow) may be directed into the cylinder **322***b* to exert a force on the piston face **332** of its piston **330** to move this piston **330** in the direction of the corresponding cylinder end **326**. This movement of the piston **330** within the cylinder **322***b* will produce a corresponding movement of the piston **330** in the other cylinder **322***a* that is in the direction of its cylinder end **328** (and that will in turn rotate the pinion **302** about its rotational axis **304** in the opposite second rotational direction to that described above). Movement of the piston **330** in the cylinder **322***a* in the direction of its cylinder end **328** again may be resisted by maintaining at least a certain pressure within the chamber **336** of the cylinder **322***a* (e.g., via pressurized fluid, for instance fluid at a pressure within a range of 50-100 psi).

The roller train **340** includes only the rollers **350** and the shoes **370**. The rollers **350** and shoes **370** are individual components and are not mounted or attached to one another. Only external forces are applied to the roller train **340** to maintain the roller train **340** in its assembled. These external forces include the compression of the roller train **340** between the pistons **330** during operation of the aircraft actuation system **300** in accordance with the foregoing. Additional external forces that may be applied to the roller train **340** include one or more of the following: 1) contact between the curved transition surface **356** of a given roller **350** and the inner surface **324** of the corresponding cylinder **322***a*, **322***b* to keep the roller train **340** from buckling with the corresponding cylinder **322***a*, **322***b;* 2) contact between a given roller **350** and the outer race **380** and/or the guide **390** after the roller exits the corresponding cylinder **322***a*, **322***b* and prior to the time this roller is disposed between the outer race **380** and the pinion **302**; and 3) contact between a given roller **350** and the outer race **380** and/or the pinion **302** when this roller **350** is disposed in the space between the outer race **380** and the pinion **302**.

In the case where the aircraft actuation system **300** is used in conjunction with nose landing gear, movement of the pinion **302** in the noted first rotational direction may be used to turn the aircraft in one direction, while movement of the pinion **302** in the noted second rotational direction may be used to turn the aircraft in an opposite direction. In the case where the aircraft actuation system **300** is used in conjunction with aircraft landing gear, movement of the pinion **302** in the noted first rotational direction may be used deploy the aircraft landing gear, while movement of the pinion **302** in the noted second rotational direction may be used to retract the aircraft landing gear. In the case where the aircraft actuation system **300** is used in conjunction with an aircraft door, movement of the pinion **302** in the noted first rotational direction may be used open the aircraft door, while movement of the pinion **302** in the noted second rotational direction may be used to close the aircraft door.

A hydraulic system for the aircraft actuation system **300** is illustrated in FIG. **8** and is identified by reference numeral **400**. The hydraulic system **400** includes a pressurized reservoir **402** (e.g., 50-100 psi), a pump, **406**, a directional control valve **408**, and a relief valve **416**. The reservoir **402** is fluidly connected with the directional control valve **408** by an outlet line **404** located at the outlet of the pump **406**. A fluid line **410***a* extends between the directional control valve **408** and the cylinder **322***a* of the aircraft actuation system **300** (to accommodate flow from the directional control valve **408** (received from the pump **406** via the outlet line **404**) to the cylinder **322***a*, and vice versa). Similarly, a fluid line **410***b* extends between the directional control valve **408** and the cylinder **322***b* of the aircraft actuation system **300** (to accommodate flow from the directional control valve **408** (received from the pump **406** via the outlet line **404**) to the cylinder **322***b*, and vice versa). A return line **412** extends between the directional control valve **408** and the reservoir **402**. A bypass line **414** extends between the outlet line **404** and the return line **412**. The outlet line **404** incorporates the pump **406**, while the bypass line **414** incorporates the relief valve **416**. The hydraulic system **400** may be used to control the flow of hydraulic fluid into and out of the cylinders **322***a*, **322***b* for the operation of the aircraft actuation system **300** in the above-noted manner.

There are a number of benefits regarding the above-noted configuration of the aircraft actuation system **300**. One is the potential reduced footprint of the aircraft actuation system **300**—the aircraft actuation system **300** may be of a length that is about only 60% of a length of a traditional rack that moves linearly to rotate a pinion for at least certain aircraft applications. The ability to have the cylinders **322***a*, **322***b* disposed in different non-colinear orientations may provide flexibility for at least certain installation configurations (e.g., in accord with the aircraft actuation system **270***b* of FIG. 3B).

Having conformal contact between each roller **350** and each associated shoe **370** (via the curved surfaces **372** of the shoes **370** being complementary-shaped to the outer perimeter of the central body **360** of the rollers **350**), in accordance with the foregoing, greatly reduces contact stress between these structures. Multiple rollers **350** being in contact with the pinion **302** at all times reduces contact stress between these components, including when a large portion of the load may be reacted by contact between one roller **450** and the pinion **302** at a given point in time. Having conformal contact between each roller **350** and the pinion **302** (when a given roller **350** is disposed within a complementary-shaped pocket **308** on the outer perimeter **306** of the pinion **302**), in accordance with the foregoing, greatly reduces contact stress between these structures.

A protocol (e.g., a method) for operating an aircraft actuation system in accordance with the foregoing is illustrated in FIG. **9** and is identified by reference numeral **420**. The aircraft actuation system includes a first cylinder and a second cylinder. The protocol **420** includes directing a first flow into the first cylinder (**422**). A first piston of the aircraft actuation system is disposed within the first cylinder and is moved by the first flow toward a first cylinder end of the first cylinder (**424**). The movement of the first piston (**424**) pushes a roller train in a first direction (**426**). This roller train extends between the first and second cylinders and may be engaged with a pinion of the aircraft actuation system throughout movement of the roller train. A second piston of the aircraft actuation system is disposed within the second cylinder and is moved by toward a second cylinder end of the second cylinder by the movement of the roller train in the first direction (**428**). A pinion of the aircraft actuation system is rotated in a first rotational direction using the movement of the roller train in the first direction (**430**). Rotation of the pinion may be used to actuate an aircraft component, as discussed above. In any case, the roller train is compressed between the first piston and the second piston based upon the pushing of the roller train in the first direction (**426**) and having pressurized fluid within the second cylinder between the second piston and the second cylinder end of the second cylinder (**432**). For instance, this pressurized fluid within the second cylinder may oppose the movement of the second piston toward the second cylinder end of the second cylinder (**428**).

Any feature of any other various aspects addressed in this disclosure that is intended to be limited to a "singular" context or the like will be clearly set forth herein by terms such as "only," "single," "limited to," or the like. Merely introducing a feature in accordance with commonly accepted antecedent basis practice does not limit the corresponding feature to the singular. Moreover, any failure to use phrases such as "at least one" also does not limit the corresponding feature to the singular. Use of the phrase "at least substantially," "at least generally," or the like in relation to a particular feature encompasses the corresponding characteristic and insubstantial variations thereof (e.g., indicating that a surface is at least substantially or at least generally flat encompasses the surface actually being flat and insubstantial variations thereof). Finally, a reference of a feature in conjunction with the phrase "in one embodiment" does not limit the use of the feature to a single embodiment.

The foregoing description has been presented for purposes of illustration and description. Furthermore, the description is not intended to limit the invention to the form disclosed herein. Consequently, variations and modifications commensurate with the above teachings, and skill and knowledge of the relevant art, are within the scope of the present disclosure. Benefits, other advantages, and solutions to problems have been described herein with regard to specific embodiments. Furthermore, the connecting lines shown in the various figures contained herein are intended to represent exemplary functional relationships and/or physical couplings between the various elements. It should be noted that many alternative or additional functional relationships or physical connections may be present in a practical system. However, the benefits, advantages, solutions to problems, and any elements that may cause any benefit, advantage, or solution to occur or become more pronounced are not to be construed as critical, required, or essential features or elements of the disclosure. The scope of the disclosure is accordingly to be limited by nothing other than the appended claims, in which reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more." Moreover, where a phrase similar to "at least one of A, B, or C" is used in the claims, it is intended that the phrase be interpreted to mean that A alone may be present in an embodiment, B alone may be present in an embodiment, C alone may be present in an embodiment, or that any combination of the elements A, B and C may be present in a single embodiment; for example, A and B, A and C, B and C, or A and B and C. Different cross-hatching is used throughout the figures to denote different parts but not necessarily to denote the same or different materials.

Systems, methods and apparatus are provided herein. In the detailed description herein, references to "one embodiment," "an embodiment," "various embodiments," etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases are not necessarily referring to the same embodiment. Further, when a particular feature, structure, or characteristic is described in connection with an embodiment, it is submitted that it is within the knowledge of one skilled in the art to affect such feature, structure, or characteristic in connection with other embodiments whether or not explicitly described. After reading the description, it will be apparent to one skilled in the relevant art(s) how to implement the disclosure in alternative embodiments.

Furthermore, no element, component, or method step in the present disclosure is intended to be dedicated to the public regardless of whether the element, component, or method step is explicitly recited in the claims. No claim element herein is to be construed under the provisions of 35 U.S.C. 112(f) unless the element is expressly recited using the phrase "means for." As used herein, the terms "comprises," "comprising," or any other variation thereof, are intended to cover a non-exclusive inclusion, such that a process, method, article, or apparatus that comprises a list of elements does not include only those elements but may include other elements not expressly listed or inherent to such process, method, article, or apparatus. Finally, it should be understood that any of the above described concepts can be used alone or in combination with any or all of the other above described concepts. Although various embodiments have been disclosed and described, one of ordinary skill in this art would recognize that certain modifications would come within the scope of this disclosure. Accordingly, the description is not intended to be exhaustive or to limit the principles described or illustrated herein to any precise form. Many modifications and variations are possible in light of the above teaching.

What is claimed is:

1. An aircraft actuation system comprising:

a pinion;

a first cylinder;

a first piston movably disposed within said first cylinder;

a second cylinder disposed in non-collinear relation with said first cylinder;

a second piston movably disposed within said second cylinder;

a transfer member interconnected with each of said first piston and said second piston, wherein at least part of said transfer member is disposed out of each of said first and second cylinders and is engaged with said pinion; and

an outer race extending from a first end of said first cylinder, around a portion of said pinion and spaced from said pinion, and to a first end of said second cylinder,

wherein movement of said first piston and said second piston within said first cylinder and said second cylinder, respectively, moves said transfer member to rotate said pinion.

2. The aircraft actuation system of claim **1**, wherein said first cylinder is parallel with said second cylinder, wherein a reference axis located between said first cylinder and said second cylinder defines a longitudinal dimension for said aircraft actuation system, wherein said first cylinder and said second cylinder are disposed at a common position in said longitudinal dimension.

3. The aircraft actuation system of claim **1**, wherein a reference axis located between said first cylinder and said second cylinder defines a longitudinal dimension for said aircraft actuation system, wherein at least one of said first cylinder and said second cylinder is disposed at an angle relative to said reference axis, and wherein an included angle between said first cylinder and said second cylinder is less than 1800.

4. The aircraft actuation system of claim **1**, wherein said transfer member is retained in compression between said first piston and said second piston.

5. The aircraft actuation system of claim **1**, wherein said transfer member comprises a plurality of rollers and a plurality of shoes, wherein each roller of said plurality of rollers is disposed in spaced relation to every other said roller of said plurality of rollers, wherein each shoe of said plurality of shoes is disposed in spaced relation to every other said shoe of said plurality of shoes, and wherein a different single said shoe is disposed between each adjacent pair of said rollers of said plurality of rollers.

6. The aircraft actuation system of claim **5**, wherein each said roller of said plurality of rollers comprises a central body, wherein said central body of each said roller of said plurality of rollers is engaged with an at least generally complementary-shaped curved surface of each said shoe that is engaged with said roller.

7. The aircraft actuation system of claim **6**, wherein said central body of each said roller of said plurality of rollers is engageable with an at least generally complementary-shaped pocket on an outer perimeter of said pinion.

8. The aircraft actuation system of claim **6**, wherein each said roller of said plurality of rollers comprises a pair of heads disposed at opposite ends of said central body, wherein each head of said pair of heads has a larger outer diameter than an outer diameter of its corresponding said central body, wherein each said head of each said roller comprises a flat end surface and a curved transition surface defined by a radius that is slightly less than a radius of an inner surface of each of said first cylinder and said second cylinder, and wherein contact between each said head of each said roller of said plurality of rollers and said inner surface of each of said first cylinder and said second cylinder is limited to said curved transition surface.

9. The aircraft actuation system of claim **1**, further comprising:

a guide disposed at least generally at said first end of each of said first cylinder and said second cylinder, disposed within an open end of said outer race and spaced inwardly of said outer race, and disposed between said pinion and each of said first cylinder and said second cylinder;

wherein said guide maintains an orientation of each said roller of said plurality of rollers prior to entering a space between said outer race and said pinion.

10. A method of operating an aircraft actuation system comprising a first cylinder and a second cylinder, wherein each of said first cylinder and said second cylinder has a first cylinder end and an oppositely disposed second cylinder end, said method comprising:

directing a first flow into said first cylinder;

moving a first piston within said first cylinder toward said first cylinder end of said first cylinder in response to said directing a first flow step;

pushing a roller train in a first direction in response to said moving a first piston step by said first flow, wherein said roller train extends between said first and second cylinders and is engaged with a pinion of said aircraft actuation system throughout said pushing a roller train in a first direction step;

moving a second piston within said second cylinder toward said second cylinder end of said second cylinder in response to said pushing a roller train in a first direction step and against a pressurized fluid within said second cylinder between said second piston and said second cylinder end of said second cylinder;

rotating said pinion in a first rotational direction using said pushing a roller train in a first direction step; and

compressing said roller train between said first piston and said second piston using each of said pushing a roller train in a first direction step and said pressurized fluid within second cylinder.

11. The method of claim **10**, wherein said compressing said roller train step comprises compressing a plurality of rollers and a plurality of shoes between said first piston and said second piston.

12. The method of claim **11**, wherein each roller of said plurality of rollers is disposed in spaced relation to every other said roller of said plurality of rollers, wherein each shoe of said plurality of shoes is disposed in spaced relation to every other said shoe of said plurality of shoes, and wherein a different single said shoe is disposed between each adjacent pair of said rollers of said plurality of rollers.

13. The method of claim **12**, wherein contact between a first roller of said plurality of rollers and each of a first shoe and a second shoe of said plurality of shoes is maintained by said compressing said roller train step.

14. The method of claim **10**, wherein said roller train extends into each of said first cylinder and said second cylinder, said method further comprising:

precluding said roller train from buckling within said first cylinder; and

precluding said roller train from buckling within said second cylinder.

15. The method of claim **10**, wherein said aircraft actuation system further comprises an outer race, said method further comprising:

precluding said roller train from buckling upon exiting said first cylinder through its said first cylinder end and prior to entering a space between said outer race and said pinion.

16. The method of claim **15**, further comprising:

precluding said roller train from buckling upon exiting said space between said outer race and said pinion and prior to entering said second cylinder through its said first cylinder end.

17. The method of claim **10**, further comprising:

directing a second flow into said second cylinder;

moving said second piston within said second cylinder and toward said first cylinder end of said second cylinder in response to said directing a second flow step;

pushing said roller train in a second direction in response to said moving said second piston step by said second flow, wherein said roller train is engaged with said pinion throughout said pushing said roller train in a second direction step;

moving said first piston within said first cylinder toward said second cylinder end of said first cylinder in response to said pushing said roller train in a second direction step and against a pressurized fluid within said first cylinder between said first piston and said second cylinder end of said first cylinder;

rotating said pinion in a second rotational direction using said pushing said roller train in a second direction step; and

compressing said roller train between said first piston and said second piston using each of said pushing said roller train in a second direction step and said pressurized fluid within first cylinder.

18. The method of claim **17**, further comprising:

providing a first actuation of an aircraft component in response to said rotating said pinion in a first rotational direction step; and

providing a second actuation of said aircraft component in response to said rotating said pinion in a second rotational direction step, wherein a result of said first actuation is different than a result of from said second actuation.

19. The method of any of claim **10**, further comprising:

providing a first actuation of an aircraft component in response to said rotating said pinion in a first rotational direction step.

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